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SCIENTIFIC RESEARCH IN THE CANNING INDUSTRY.*

BY

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In September, 1913, Dr. A. D. Little delivered the annual address as President of the American Chemical Society. His subject was "Industrial Research in America," and his address began with the following words:

"Germany has long been recognized as preëminently the country of organized research. The spirit of research is there imminent throughout the entire social structure. This is not the time or place, however, nor is it necessary before this audience, to refer in any detail to the long record of splendid achievement made by German research during the last fifty years. It is inscribed in luminous letters around the rock upon which Germany now stands secure among the nations of the world.

"The virility and range of German research were never greater than they are to-day. Never before have the superb energy and calculated audacity of German technical directors and German financiers transformed so quickly and so surely the triumphs of the laboratory into industrial conquests. Never has the future held richer promise or orderly and sustained progress, and yet the preëminence of Germany in industrial research is by

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* Presented at a meeting of the Section of Physics and Chemistry held Thursday, March 7, 1918.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

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no means indefinitely assured. A new competitor is even now girding up his loins and training for the race, and that competitor is, strangely enough, the United States—that prodigal among nations, still justly stigmatized as the most wasteful, careless, and improvident of them all."

He then discussed briefly some of the more striking illustrations of industrial research in this country. As we listened to this comprehensive survey we little realized the transformation that was so soon to begin in the field of industrial research throughout the world.

In the late summer of 1914 Europe was suddenly convulsed with the present war. Instead of mere armies being pitted against each other, whole nations, with all their resources, were involved. It soon became evident that the long development of the German nation in industrial research gave that country an important advantage which could only be offset by a systematic organization of the scientific resources of the countries opposing her. Unfortunately, in the early days of the war, the scientific men of England and France were sent to the trenches, where many of them were sacrificed. Steps were finally taken to restore to the laboratories those who were left, and industrial research was organized on a scale which had not been contemplated before.

Within the first few months of the war Great Britain decided that the system of industrial research of the nature found necessary in war time should be extended and placed on a permanent basis, and an organization was effected looking to that end. On July 28, 1915, approximately eleven months after the beginning of the war, a committee of the Privy Council was appointed to direct the application of any sums of money provided by Parliament for the organization and development of scientific and industrial research. An Advisory Council was also appointed, and to it were referred recommendations:

(I) For instituting specific researches;

(II) For establishing or developing special institutions or departments of existing institutions for the scientific study of problems affecting particular industries and trades, and

(III) For the establishment and award of research studentships and fellowships.

It is especially noteworthy that the Advisory Council did not limit the scope of its plan to industries necessary for the prosecution of the war. Not only was it concerned with research as supported by the government or conducted by educational institutions, but also with encouraging coöperative industrial research conducted partly or entirely by manufacturing and trade organizations.

The Advisory Council has issued two reports which show that the work has been surveyed on a scale and in a manner that must necessarily exert a sweeping influence on manufacturing industries. The overseas dominions, including Canada, Australia, South Africa, and New Zealand, have appointed appropriate councils and taken action in line with the movement of the Advisory Council of Great Britain.

It is obvious that systematic coöperation of this kind must necessarily advance the manufacturing industries and the public welfare. The movement marks a new epoch in the world's history. On this subject the Advisory Council says:

" It will inevitably tend to bring industries into intimate relation, which are at present independent of each other; to transform what have hitherto been crafts into scientific industries, and to require coöperation not only between different firms in the same industry, but between groups of industries in a continuously widening series of interrelated trades."

Active coöperative research in connection with the manufacturing departments of corporations that have known each other only as rivals represents a wide departure from our customary habits of thought. Under ordinary conditions so important a step would be taken only after great deliberation. The progress made, therefore, may be attributed to the patriotism of British manufacturers.

Even in the first report of the Advisory Council it is stated that

" There are indications of a change of view among certain firms which give us hope that a more far-reaching coöperation may be possible, and we understand that the necessities of this war have led to an exchange of information once tenaciously reserved, which may survive the present critical days and, if it does, will augur well for the future."

The same report also says:

" The necessity for the central control of our machinery of war had been obvious for centuries, but the essential unity of the knowledge which supports both the military and industrial efforts of the country was not generally understood until the present war revealed it in so many directions as to bring it home to all. War has remained as much an art as ever, but its instruments, originally the work of the craftsman and the artist, are now not only forged by the man of science; they need a scientific training for their effective use. This is equally true of the weapons of industry. The brains, even the very processes, that to-day are necessary to the output of munitions were yesterday needed, and will be needed again to-morrow, for the arts of peace."

It is now generally recognized that at the beginning of the war scientific research in the United States was better organized than in any other country, with the exception of Germany. During the last three years scientific research in the United States has increased by leaps and bounds. Great Britain, however, has far outstripped us. Her early participation in the war necessitated the utmost activity in scientific research. Her systematic encouragement of coöperation in this field of labor has resulted in unprecedented advancement. It must be a great satisfaction to us all that the action of Great Britain in encouraging coöperative research is being carefully studied in this country, and the advisability of organizing a similar system of coöperation here is actively discussed.

In view of this great world-wide movement in the broad question of industrial research, I have some hesitation in addressing you this evening in regard to the scientific research that has been conducted and is now under way in a relatively small field of industry. Yet it is of interest to note that at the time Mr. Little delivered the address to which I have referred the research laboratories of the National Canners' Association were being equipped and organized and, at the time the ideas of Great Britain on the subject of coöperative industrial research were formulating, these laboratories had been established and afforded the first instance in this country of a permanent organization for coöperative research maintained by an organized industry.

The canning industry has presented a field with which science has played small part. The first experimental work from which was evolved the process of sterilizing in hermetically sealed containers was conducted before the day of Pasteur and before the idea of sterilization was conceived. The present canning technology was developed by means of an immense amount of experimental work, sometimes conducted in a systematic manner, but often more or less haphazard. The records of this experimental work are not available. Thus countless repetitions have occurred and a world of effort and experience has been lost. With trained observers, experienced in scientific research, much greater progress might have been expected.

From time to time various problems and difficulties were referred to scientific men not familiar with the industry, but, for the most part, the problems given them were incompletely or incorrectly stated or the workers had not the opportunity to grasp the full scope of the questions submitted to them.

Still there were several incursions of scientific men into the problems of the canning industry which resulted in great good. Among these may be especially mentioned the work of Russel in 1895, of Prescott and Underwood in 1896 and on three subsequent occasions, and of Harding and Nicholson in 1903. These articles—all on bacteriological subjects—while describing work which was not carried out to the extent that might have been desirable, were fundamental in their character and gave to the industry new data and new ideas whose value cannot be overestimated.

The idea of systematic research in connection with the canning industry is a very recent development. Only a relatively short time ago the industry was governed largely by trade secrets, and the methods of the canner were shrouded in mystery. Within the memory of men still operating the process, man was supposed to be possessed of secrets which were guarded from even the proprietor of the establishment in which he was employed, and the process-room was a place of mystery to which no one but the man who controlled its operations was admitted. At the present time this condition of affairs has been reversed, and technical processes are now openly discussed. The operatives of competing manufacturers commonly consult each other with the utmost freedom regarding the technology of the industry, and such consultations result in material progress. This transition from the era of trade secrets to the era of helpful collaboration was not a simple step, but rather a gradual development. The important thing is that it has been accomplished.

In connection with this transition, there has grown up the recognition of the need of systematic scientific study, which has been somewhat gradually developed and has been placed upon a coöperative basis. Unfortunately, this work has had to be extended over a greater field than would have been necessary if coöperative research had been general in the industries of the country. It has been necessary to take up as fundamental some of the questions which should have been studied earlier by other industries. For this reason the work has not been as intensive as it would otherwise have been.

The interests and responsibilities of the canner cover a much broader field than is usually supposed. They begin with the planting of the seed and continue until the finished product is finally consumed. The canner must give active personal attention to the growing of his crops, because some of his most important problems are purely agricultural. The acreage must be ample and the seeding so arranged that the harvest will be distributed with as much uniformity as practicable over a relatively long season, in order that the plant may be kept in operation regularly and for the maximum time. The greatest care must be exercised to harvest each field at the proper stage of maturity. The raw product must be of high grade, or the finished product will be inferior. Finally, the crop must be profitable to the grower, or he will turn his attention to other crops.

The canner, therefore, in addition to securing contracts for the acreage he desires, must give his personal attention to the character of seed planted, the methods of cultivation, the use of fertilizers, and the fighting of insect and fungous pests that may be encountered. Fortunately, all of these problems come within the general field of agriculture, and an army of well-trained men have given them attention in the Department of Agriculture and in the various State Experiment Stations. These agencies, moreover, are always ready to give assistance and to investigate new problems that may arise in their fields. Still, such new problems are constantly arising, and especially problems which are new to an individual locality, and the canning industry could not succeed without keeping in close touch with the various agencies engaged in agricultural research.

After the raw product is received at the canning plant, each of the operations necessary for the completion of the canned article presents problems which often require investigation. An experienced employee must make frequent inspections of the product at every stage of its preparation and, whenever any abnormal condition appears, the cause must be discovered and removed.

The problems that present themselves are of the most diverse nature. Difficulties frequently arise while the product is being canned and must be solved quickly and remedied if a normal product is to be secured. More frequently, however, difficulties are encountered after the product is canned. They may be apparent when samples are opened for inspection as soon as the canning operations are completed, or they may develop on storage. Such difficulties can be adequately studied only by men who are thoroughly conversant with the technology of the industry.

Among the experienced men of the canning industry there is already a world of information regarding questions of this kind. Unfortunately, this information is not always accurate, and opinions of experienced packers are frequently conflicting. Many skilled operatives have considered only a part of the conditions under which they were working and, as a result, have drawn wrong conclusions. The attention to such questions of trained observers, therefore, must necessarily be of value.

As an illustration of the difficulties referred to may be mentioned a general dark-gray discoloration in canned corn. This has been encountered rarely, but where it has been found it occurred in considerable amount. Its study showed that it was due to a mere trace of copper coming from the cooker in which the corn was heated before being filled into the can. While the plant was in operation this color was not produced. It sometimes happens, however, that as a season nears the end a plant shuts down for a few days and then starts again to take care of some belated fields. In this interval a slight tarnish forms on the copper surface of the cooker valves and is not removed by careful scrubbing. When the canning of the corn is resumed this film of copper oxide is dissolved and passes into the corn. Then, when the corn is sterilized after the can is sealed, the infinitesimal trace of hydrogen sulphide which is always formed when any food is cooked converts the dissolved copper into sulphide, which, in the colloidal form, exerts a marked coloring action on the product. In this way one ten-thousandth of one per cent. imparts to the corn a dark-gray color which is unattractive to the eye. The cause being known, the remedy was obvious, and this particular difficulty caused no further trouble. This one instance is cited merely as an illustration of a broad class of problems that arise from difficulties in the daily work of the industry.

SPOILAGE.

Spoilage in canned foods betrays itself either by the swelling of the can or by the abnormal taste or appearance of the food. Usually it occurs rapidly and is evident a day or two after the food is packed. It is always due to faulty technic, and it is of the utmost importance to the manufacturer to locate the cause of the spoilage and provide a remedy at the earliest possible moment.

When we remember that the rate of penetration of heat through the contents of a can depends largely on the physical nature of the food, it is evident that slight changes in the character of the food will greatly influence the time of heating necessary for sterilization.

The temperature and time required for the sterilization of a particular food sometimes vary in different seasons and in different parts of the country. It may happen, therefore, that a canner will find his product undergoing spoilage, though it was put up by a method which had always been satisfactory before.

Again, spoilage is often due to the can not being properly closed. The brief duration of the canning season makes it difficult to have the factory manned with a sufficient number of highly skilled operatives. It sometimes happens, therefore, especially when working with a new type of can, that the closing machine will not be properly adjusted, and cans closed with it will contain a leak so slight as to be very difficult of detection and yet sufficient to cause the contamination of the contents.

Then the process man may be misinformed regarding the capacity of some machine he is using. Sometimes the temperature is not uniform in all parts of the sterilizing equipment, so that in processing the cans do not receive the temperature indicated for the required time.

When we consider that a given case of spoilage may be due to one or several of these causes or to a variety of similar reasons, it is apparent that the cause of spoilage is frequently difficult to determine, and both skill and experience are necessary to make this determination accurately and quickly.

But spoilage does not necessarily occur while the goods are being packed. It is sometimes due to organisms which multiply slowly, especially at the temperature at which the goods are stored. In such cases it appears only after the goods have been stored for a considerable time, either in the canning plant or after distribution. When spoilage of this nature is discovered it is, of course, important to locate its cause as promptly as possible and to determine its probable extent.

In connection with a question of spoilage, however, whether it occurs while the food is being packed or while it is in storage, the important thing is to understand and learn to safeguard against it.

BY-PRODUCTS.

Much has been said of the possibility of utilizing by-products of the canning industry. On the whole, great progress has been made in the matter. Many products, such as cobs and husks of corn and the vines of peas, are used directly for feeding stock or are preserved in silos for use in winter.

A relatively small number of by-products are used in the manufacture of fertilizers or are applied directly to the fertilization of the soil. There are still, however, countless tons of material whose removal is only an expense to the industry and for which no use has yet been found. It is frequently pointed out that much of this material has a certain food value and, if placed in such form that it could be preserved and transported, would add to the food supply available for our domestic animals. In these matters, however, it must always be kept in mind that to dry a product containing 90 per cent. or more of water is a relatively expensive operation. When we consider the large volume of this material in a single canning plant it will be understood that the drying of the offal would require an elaborate and expensive equipment. Most canning plants are operated only for a few weeks in the year and on this account cannot consider an expenditure for " overhead " which could be carried readily by a plant running continuously.

It must also be remembered that, during the canning season, all the facilities of the canner are taxed and it is a difficult matter for him to secure the labor necessary for his ordinary operations—

let alone the drying of the by-products and placing them in suitable form for shipment. It has been suggested that such by-products be prepared for commerce at central plants to which they would have to be delivered from the separate canneries. Even if this were done, however, preliminary drying would be necessary at the canning plant. In summer and early fall, when most of the canning is done, spoilage occurs rapidly, and all by-products, if they are to be handled at all, must be dried immediately.

This question is now being studied by competent engineers. I have no doubt much progress will still be made in the matter of disposing of the by-products of the canning industry. It must be borne in mind, however, that the question has limitations which are not apparent to the cursory observor, who is inclined to criticise the canner when he sees tomato peelings or pomace hauled away from the plant at a direct expense.

SANITATION.

In addition to the peelings, trimming stock, and other solid material just referred to, there is frequently a considerable amount of liquid waste and wash-water whose disposal is difficult in some localities. Under some circumstances such products become a nuisance in the community, and their cure offers new problems in sanitary engineering. This is a matter to which sufficient attention has not been given, but it is being studied by the Public Health Service and other agencies.

Methods of treatment have been devised for handling the liquid waste from some types of canning plants, and progress has been made in others.

TIN PLATE.

Industrial research in the canning industry must cover a much broader field than would be necessary if coöperative industrial research had been adopted by your manufacturing industries a generation ago. Defective tin plate has been believed by some canners to be responsible for many difficulties of the industry.

Under bad storage conditions cans frequently rust on the outside. This gives them an unattractive appearance and, if the rusting continues, sometimes causes perforation of the can and spoilage of the contents. With some light-colored products, such as corn, patches of a dark pulverulent substance occur on the inside of the can. Sometimes acid fruits perforate the cans and thus permit the contents to spoil.

These phenomena and many others have long suggested the thought that imperfections in the tin plate or faults in its manufacture might be responsible for some of the canner's troubles. Many studies of tin plate were undertaken, but the expense involved was so great and the amount of detail so enormous that the investigations were not made sufficiently comprehensive to be of material value.

Finally, in 1915, a collaborative study was begun of the relative value of different weights of tin coating on canned food containers. This investigation was conducted by a joint committee representing the laboratories of the American Can Company, The American Sheet and Tin Plate Company, and the National Canners' Association. Two representatives of the Bureau of Chemistry were also associated with the committee, participating in all the work and taking part in the discussions. The committee reported early in 1917.

As might be expected in an investigation of this scope, the study suggested more question than it settled. Yet it did afford conclusive answers to some important questions. Among these are the following:

1. None of the difficulties with canned foods that have been attributed to tin plate are caused entirely or even largely by light or defective coating.

2. No weight of coating will overcome faulty technic or faulty storage in the finished product.

3. When cans are stored under conditions that promote rusting, heavy coating will retard rusting, but will not prevent it.

4. The various discolorations on the inner surface of the can and in the contents have no relation to weight of coating.

But it is evident that there may be other considerations in tin plate than weight of coating. The importance of the composition of steel and of the conditions of its treatment in other industries emphasize the probable importance of the same considerations in connection with tin plate. As stated above, the canner is interested, among other things, in the rusting of the exterior of the can, the corrosion and formation of undesirable colors on the inner surface, and in localized corrosion resulting in perforations and leading eventually to spoilage. We cannot tell, without a comprehensive experimental study, whether these conditions will be influenced by the composition of the steel, the character of its surface, the temperature of annealing, or other conditions of manufacture.

A comprehensive collaborative investigation of this subject was instituted a few months ago by the laboratories of the American Can Company, the Titanium Alloy Manufacturing Company, and the National Canners' Association. This investigation may require several years for its completion, but it is being conducted on so elaborate a scale that it is believed the results will be conclusive and fundamental.

FOOD POISONING.

The responsibility of the food manufacturer does not cease even when the food has passed into the hands of the consumer. There is a general popular impression that food poisoning is likely to be produced by this food or that, and many people are prone to attribute an attack of indigestion to poisoning caused by a particular food.

Then it is well known that cases of food poisoning do occur, due to the infection of the food at some period in its history. This infection may occur at the time of the original harvesting of the food or at the time of its preparation in the form in which it is placed on the market or it may occur in the preparation of the food for the table after it reaches the hands of the consumer.

In any case, our information regarding the general question of food poisoning is altogether inadequate, and it is of the utmost importance to manufacturers and handlers of food that our information on this subject be made more complete. This is also of importance to the medical profession, and especially to the public.

The canning industry has long felt the need of an adequate survey of this subject by responsible parties, and something more than a year ago invited the National Research Council to organize a systematic investigation of this subject and designate people who were to conduct it, the investigation being supported by the industry. After careful consideration, the National Research Council accepted this invitation and organized the investigation, naming as director, Dr. M. J. Rosenau, head of the Department of Preventive Medicine and Hygiene of Harvard Medical School. The work was undertaken in June and is being actively continued.

THE PRESENT CONDITION OF THE INDUSTRY.

In view of the unprecedented conditions that now confront us, it seems best to digress for a few moments from the subject of the evening and discuss briefly the present situation in the canning industry.

During the last season there were packed, in round numbers:

Tomatoes	15,000,000 cases, of 24 cans each.
Corn	11,000,000 cases, of 24 cans each.
Peas	10,000,000 cases, of 24 cans each.
Other vegetables	13,000,000 cases, of 24 cans each.
Fruits	11,000,000 cases, of 24 cans each.
Evaporated and condensed milk	30,000,000 cases, of 48 cans each.

When we add to this total of 90,000,000 cases the pack of other varieties of canned foods, including the various kinds of fish and shellfish, and an unprecedented pack of meat products, we have a grand total of more than six billion cans.

In normal times a pack of this size would mean low prices, yet high prices prevail and must prevail, as they do in other industries. Everything the canner uses has increased in cost: cans, labels, boxes, nails, sugar, coal, machinery—every article used directly or indirectly in the operation of the factory and in preparing and shipping the food. Because of the shortness of the canning season an adequate supply of skilled labor is scarcely available even in normal times. Now the difficulty of securing labor presents an obstacle that is almost insurmountable.

Then we have an enormous increase in the cost of raw products. The grower gives preference to the crop that will give him the greatest return. It is no simple matter to pay enough for canners' crops to compete with $2.25 wheat and with corn at a proportionate price. Moreover, wheat and corn require little labor. Most canners' crops require much, and labor is not available. Perhaps the cost of producing canned food under present conditions is best understood when we remember that both canners and wholesalers are licensed by the Food Administration and are not permitted to make a higher charge for staple products than is necessary to yield them a fair profit.

No prediction can yet be made regarding the probable pack of the present year. The Army and Navy will require about 35 per cent. of a normal pack of tomatoes and 25 per cent. of a normal pack of corn, peas, salmon, and sardines. The Army and Navy and the civilian population of our Allies will require ten million cases of milk if bottoms can be secured for its transportation. All these products must go from America, for no country in Europe can grow the food needed by its own people. It is known to all that canned foods are preserved by heat alone in hermetically sealed containers. They afford us the nearest approach we know to fresh cooked food. It is only in this form that the substantial equivalent of fresh foods can be supplied to our Army and Navy and to the military and civilian population of our Allies. Almost every variety of food that is cooked can be preserved by canning and is actually on the market in the can.

Desiccated foods have a promising outlook, but with many products are still in the experimental stage. Desiccated tomatoes, corn, and peas are unknown in a commercial way, except for the preparation of soups. We do not know whether they will be acceptable to the public. We know little of the technological difficulties still to be overcome in their commercial production. So far as experience has gone, there is no reason to believe that the manufacture of desiccated foods may not grow to large proportions—but it must be a growth. A large industry cannot spring into being. In any case, the present wants of the Army and Navy for tomatoes, corn, and peas must be supplied with the canned product.

No estimate can be made of the extent to which growers will be willing to contract for acreage in canners' crops.

Supplies of pig tin are always a source of anxiety. The amount on hand is never sufficient to make the future secure. Recently the condition in this respect has been less satisfactory than usual. Our chief anxiety regarding the supply of tin plate, however, is the lack of production of both plate and cans owing to transportation difficulties.

The plans of the early winter for the manufacture of plate and cans were impossible of execution. The many demands on the transportation system made it impossible to move plate from its place of production to the makers of cans, and, as a result, some can-making plants found it necessary to shut down for a time because of lack of plate, while, on the other hand, some plate manufacturers filled their storerooms and then were compelled to close their plants because of lack of additional storage space. Under these circumstances, accurate predictions cannot be made. We can only say that the requisite number of food containers for the coming season will not be available.

A METHOD FOR THE DETERMINATION OF THE RELATION BETWEEN VAPOR PRESSURES AND THEIR CORRESPONDING TEMPERATURES AT PRESSURES OF LESS THAN FIVE MILLIMETRES.*

BY

W. R. HAM, Ph.D., J. C. CHURCHILL, M.S., and H. M. RYDER, M.S.

THE object of this work was the development of a method whereby the relations between vapor pressures and their corresponding temperatures might be determined for pressures of less than five millimetres, and especially for pressures of less than one millimetre of mercury.

Most data published to date on the matter of vapor pressures are confined to minimum pressures of five millimetres of mercury or greater, although a few give values of one millimetre. This has been partly due, no doubt, to the difficulties in the past of obtaining a fairly high vacuum in a large system, or in a system which could not be hermetically sealed, and partly to the inability to read low pressures accurately by means of an ordinary mercury column. The most accurate readings obtainable with any ordinary mercury column, or with a U-tube, will probably vary at least a few tenths of a millimetre from the true value. Ramsay[1] did not rely on a U-tube manometer for values of less than 2.5 millimetres. The McLeod gauge has been known for a long time, but results obtained from it are of no value where the gas contains vapor, or even for such gases as air, nitrogen, etc., which probably condense to a certain extent. Ramsay[2] found the McLeod gauge to be reliable for hydrogen down to a very low pressure by comparing gauges of different dimensions, and by calculating the values, knowing the volume of the cylinder of his pump and the volume of his system. A method which would permit of measurements of vapor pressures by a McLeod gauge, and at the same time would permit of the use of pure hydrogen in the gauge, would enable low vapor pressures to be measured accurately. In recent years vacuum pumps have been placed on the market which will pump very rapidly down to 0.05 millimetre on a small closed system, and to a somewhat higher pressure on large systems, thus making practicable the consideration of the determination of very low vapor pressures.

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* Communicated by Doctor Ham.

[1] Travers, "Experimental Study of Gases."

[2] *Ibid.*

Biot, according to Preston,[3] expresses the relation between the vapor pressure of a substance and its corresponding temperature in the formula

$$\log P=A+Bb^{T}$$

or more generally

$$\log P=A+Bb^{T}+Cc^{T}+Dd^{T}+\ \ldots\ldots,$$

where A, B, C, D, b, c, d are constants to be determined by experiment.

Roche [3] offers

$$P=Aa^{mT}-n^{T}$$

but which Regnault [3] found to be somewhat more approximate than that offered by Biot.

Clausius [4] expresses the relation between vapor pressure and temperature by means of the formula

$$\frac{d\log P}{dT}=\frac{-L_2}{RT}$$

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[3] Preston, "Theory of Heat."

[4] Knox, "Physics—Chemical Calculation," p. 25, 1912.

where P is the pressure, T is the absolute temperature, L is the molecular heat of evaporation, and R is a constant, its value depending on the units used. If L were a constant this would give an equation easily handled where L is known, but as L is a variable, and in general some function of T, the equation becomes involved, if not impracticable. A combination of this equation and Biot's shows that

$$L = RT^2 b^T$$

which is not a very convenient quantity with which to work.

Rankine [5] offers the formula

$$\log P = A - \frac{B}{T} - \frac{C}{T^2}$$

with the values as above. In offering this formula Rankine presents the first two terms of the right-hand side of the equation from a theoretical consideration of molecular activity. These considerations, however, leave undetermined a variable quantity, which is, in general, some function of the density of the liquid, which in turn is variable, and the change in what he pleases to call the " Superficial atomic elasticity " of the liquid or solid from which the vapor is obtained. To correct this, he adds arbitrarily the third term, $\frac{C}{T^2}$, which form suggested itself from a study of the variations between observed results and those calculated from the equation, not using the third term. Rankine's formula and the one offered by Biot are used in later considerations.

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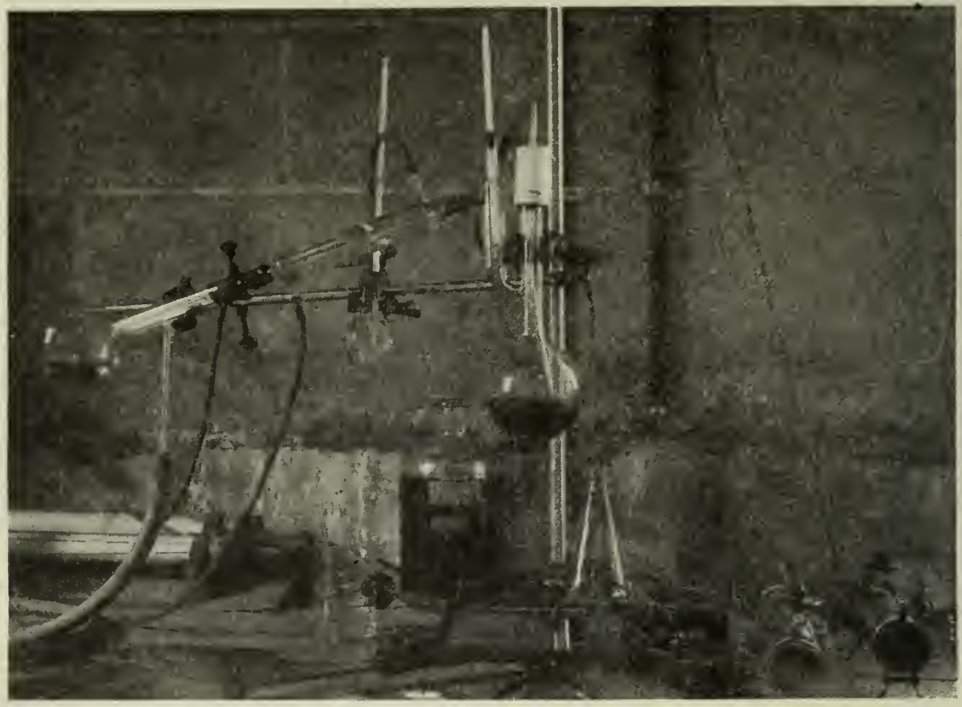
[5] Rankine's " Miscellaneous Scientific Papers," Griffin, 1881.

In connection with this work, the term "Boiling" of the liquid may hardly be said to apply, as at the lower pressures the giving off of vapors by the liquid is not accompanied, necessarily, by ebullition. This is probably due to the fact that the pressure on the liquid a few millimeters below the surface is very much greater, relatively, than at the surface, and a considerably higher temperature would be required to cause a rapid formation of vapor. The purity of the liquid and the smooth interior of the vessel would probably also permit of considerable superheating of the liquid before ebullition would take place.



The accompanying photographs and diagram will give an idea of the apparatus used. The still is shown on the right, in the diagram, and consisted of a chamber, *a*, for heating the liquid; a chamber, *b*, in which the thermometer was placed, and which was covered with tin foil and cotton during the tests; a condenser, *c*, with a water jacket; a receiver, *d*, which collected the distillate;

a second receiver, *e*, which was packed in ice and which served to keep any vapor from passing to the rest of the system; an electric heating element, *f*, consisting of a platinum coil wound on a glass rod and immersed in the liquid, which was the source of heat, and which was controlled by means of the rheostat, *g*. The leads from the exterior to the heating element consisted of glass tubes through a rubber stopper, a mercury column serving as conductor in each.

The remainder of the apparatus consisted of the remaining portion of the vapor system, and the hydrogen system. A drying tube, *h* (phosphorus pentoxide), was placed next to the cold receiver as a further provision against the movement of any vapor to the remainder of the system. The reservoir, *i*, of about 20 litres capacity, was used to prevent any sudden fluctuations in pressure and to render negligible any small leaks. A U-tube, *j*, was used as a rough indicator of the pressure in the system.

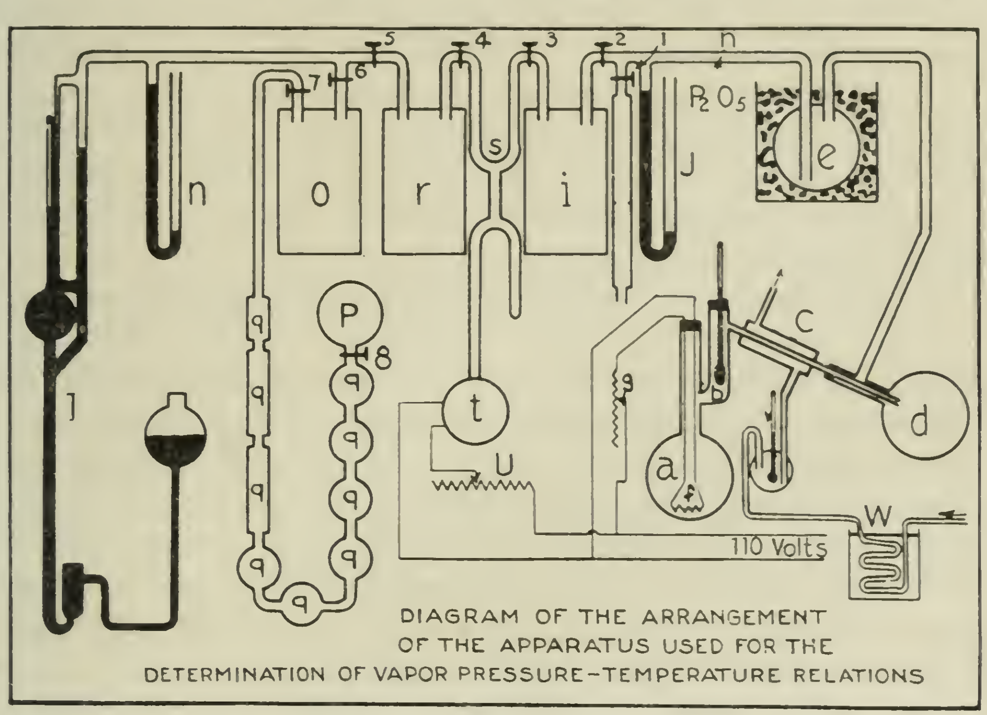


DIAGRAM OF THE ARRANGEMENT OF THE APPARATUS USED FOR THE DETERMINATION OF VAPOR PRESSURE–TEMPERATURE RELATIONS

The hydrogen system consisted of a McLeod gauge, *l*, with a cathetometer; a U-tube, *n*, a hydrogen reservoir, *o*, which was supplied with hydrogen from a Kipp generator, *p*, the hydrogen being washed and dried by passing through the bottles and tubes, *q*; and a reservoir, *r*, used, as in the case of the vapor system, to render the pressure in the system more stable.

The two systems were joined at *s*, with the tubing shaped as shown, and connections were also made here with the pump. Provision was here made for a second pump, in case more rapid pumping should be desired. The pump used was a May-Nelson two-ring pump, *t*. The electrical circuit was arranged with a rheostat, *u*, so that the speed of the pump could be readily controlled.

In order to seal the system as perfectly as possible, all stoppers and rubber-tube connections were sealed with mercury, and all stopcocks were similarly protected. Whenever air was let into the vapor system it was first thoroughly dried in order that water vapor might be excluded. In addition to this, all of the large reservoirs contained phosphorus pentoxide. A thermometer, *v*, indicated the temperature of the water passing through the cooling jacket, and a coil, *w*, was provided, in case it should be necessary to heat the circulating water for cooling, when a substance of high freezing-point was used.

In describing the method followed in the determination of the vapor-pressure temperature relations, it seems desirable to consider first the measurement of pressure, and then the determination of the temperature of the vapor at this pressure.

In order to eliminate any air from the liquid, the vapor system was first pumped down and the liquid in the still boiled for a few minutes. For this work stopcocks Nos. 2 and 3 were open and the remainder closed. With the pump running, the liquid was then allowed to cool for a time. With a considerably higher pressure in the hydrogen system, stopcocks Nos. 5 and 4 were opened. This caused a quantity of hydrogen to pass into the vapor system, and the pump then worked on both the hydrogen and the vapor systems. The pump was permitted to continue for several hours, the degree of vacuum at the end of this time being determined by the speed of the pump. If a fairly high vacuum was wanted, the pump was operated at a higher speed.

When the desired vacuum was reached, the reservoir of the McLeod gauge was raised and stopcock No. 3 was closed, and the determination of the temperature was carried on in the closed system. The pump was, however, permitted to operate on the hydrogen system, in order that the pressure on the mercury column in the McLeod gauge might be reduced to a negligible quantity, if it were not already so. The gauge was permitted to stand for some time, and the readings were then taken and the pressure calculated. The pressure thus obtained was assumed to be the pressure in the receiver of the still. This assumption was allowable for the following reasons:

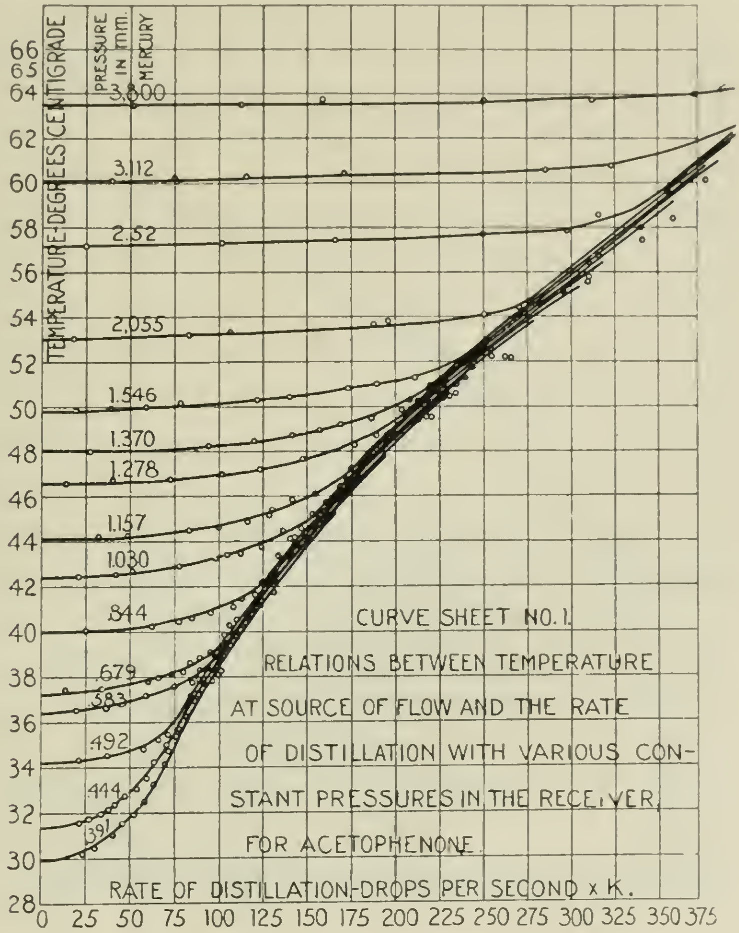
If there was no flow of gas in the system, the pressure in the gauge would be the pressure in the system at the receiver. To approach this, the pump was operated very slowly toward the last, so that the flow of gas was reduced to a minimum. Further, the pump was working on the apparatus at almost its exact centre, so that what flow of gas there might be, was from either end toward the centre. Theoretically, if the two halves of the system offered equal resistance to the flow of gas, the pressure in the receiver would equal the pressure in the guage. However, even though this was not exactly the case, the effect of the flow on one side largely counteracted the effect of the flow on the other side, and this fact, together with the fact that the flow was reduced to an almost, if not altogether negligible quantity, will show that the assumption made above does not detract from the value of the results.

Other theoretical approximations might result from leakage in the system and from inaccuracies in the working and reading of the gauge itself. The system was carefully tested as to its ability to hold a vacuum, and the leaks were found to be negligible. From tests made on the gauge, it was found that if the gas was highly compressed in the capillary tube the readings were somewhat lower than when it was not so highly compressed. However, with the longer column of gas above the mercury in the closed tube, for various lengths of column, very consistent readings were obtained. It was also observed that on expanding and contracting the gas the readings as calculated from the gauge would not change. Any vapor in the gas would cause very erratic readings, but it is very improbable that vapor would get into the gauge in this system, since it was originally filled with pure hydrogen, and after pumping began the flow was always away from the gauge and through a system of considerable capacity.

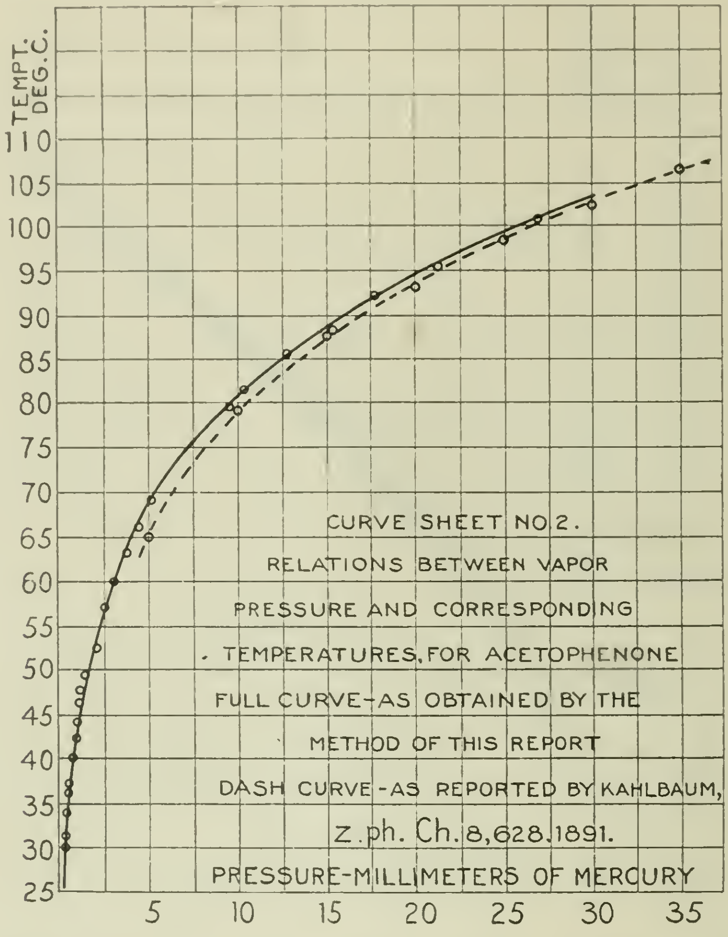
In order to determine the temperature of the vapor at the pressure in the receiver, it was necessary to make the pressure at the thermometer equal to the pressure in the receiver and at the same time have a saturated vapor enveloping the thermometer. This is easily accomplished at relatively high pressures, but at very low pressures a very slight flow of vapor from the thermometer chamber to the receiver might mean an enormous relative increase in the pressure at the thermometer over the pressure in the receiver. On the other hand, if the flow of vapor ceases, it is very probable that the thermometer is not entirely enveloped in a saturated vapor, and hence it would indicate values too low. In view of this, in order to accurately determine the temperature of the vapor corresponding to the pressure in the receiver, the following procedure was adopted:

The liquid in the still was raised to such a temperature that there was a considerable flow of gas past the thermometer, as evidenced by the condensed vapors flowing into the receiver from the condenser. The pressure at the thermometer was then obviously greater than in the receiver, so that the thermometer reading must be greater than the desired value. Observations were then taken of the rate of distillation (a measure of the current of vapor) as evidenced by the number of drops of liquid entering the receiver in a given time, and the thermometer reading. The rate of distillation was then reduced and readings were again taken. This process was repeated until the movement of vapor almost ceased. A curve was then plotted (see curve sheet No. 1) between pressure as ordinates and the rate of distillation as abscissæ, and this curve extended to the point of zero rate of flow. The temperature corresponding to this condition must necessarily be the temperature of the vapor at the thermometer at the condition of zero rate of distillation; that is, with the pressure at the thermometer the same as the pressure in the receiver. Knowledge of the pressure in the receiver will then furnish the necessary data for one point on the vapor pressure—temperature curve for the liquid. A repetition of this process for other pressures in the receiver will enable any number of points on the curve to be determined. Curve sheet No. 1 shows a series of curves plotted between temperature readings of the thermometer and rates of distillation for various pressures in the receiver. It will be noticed that each curve, to a certain point, follows a general one (moving from right to left), which is convex upward. From this point the curve becomes convex downward, and approaches a horizontal line whose value in degrees, as has been stated before, is the temperature corresponding to the vapor pressure in the receiver, since at this point the pressure in the receiver is the same as at the thermometer. At all other points on the curve, then, the pressure at the thermometer is greater than in the receiver.

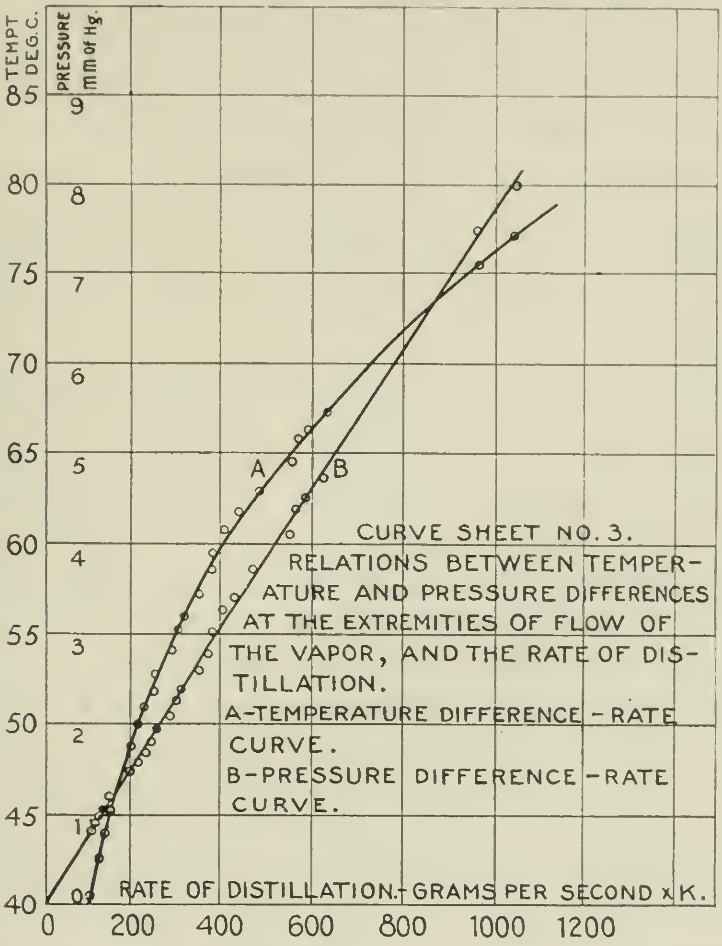
Since the rate of distillation is given in terms of drops of condensed vapor passing into the receiver in a given time, and since, when being formed rather slowly, the drops of a given liquid will, at a given temperature, be sensibly the same in size, and therefore weight, and since the temperature of the condensed vapor was at all times practically constant, the measure of the rate of distillation as made will also be a measure of the current of vapor passing the thermometer, in terms of some constant times the weight of the vapor passing a point per unit time.



The general curve referred to is, then, a curve plotted between the current of vapor and the temperature as recorded by the thermometer. Since there is some relation between vapor pressure and temperature ($T = f(P)$), and since the cause of the flow is $(P-P_0)$ where P is the pressure at the thermometer and P_0 is the constant pressure in the receiver, the curve gives a relation between the same function of the difference of pressure, with the zero point of the ordinate properly transformed, and the current. If a curve is plotted between the current and P, instead of between the current and $f(P)$, this curve expresses the relation between the difference of pressure and the current. The slope of this curve at any point will, then, be a measure of the resistance the path offers to the flow of the current under the particular conditions. Curve sheet No. 3 shows curve *A* plotted between the temperature readings of the thermometer and the current. Curve *B* is a similar curve showing the relations between the current and P, instead of $f(P)$, the values of P corresponding to t being obtained from curve sheet No. 2. It is obvious that curve *B* is a straight line passing through the origin. This would indicate that the quantity of matter passing from the thermometer



chamber to the receiver per unit time is proportional to the difference of pressure. That this should be so, within the limits of accuracy of the method, will be obvious, since the physical dimensions are constant for the path, since the linear velocity of the flow is inversely proportional to the density of the vapor, and since any increase in friction or viscosity due to an increase in density is a quantity too small to realize in a work of this sort.


CURVE SHEET NO. 3.
RELATIONS BETWEEN TEMPERATURE AND PRESSURE DIFFERENCES AT THE EXTREMITIES OF FLOW OF THE VAPOR, AND THE RATE OF DISTILLATION.
A—TEMPERATURE DIFFERENCE—RATE CURVE.
B—PRESSURE DIFFERENCE—RATE CURVE.

This straight-line curve will also serve as an excellent check on both the temperature-rate curves and the vapor pressure-temperature curve, as each of these curves contains quantities which are independent of the other.

In the actual plotting of the curves on curve sheet No. 1, the points on the upper parts of the curves were not determined with sufficient accuracy to show that the curves become parallel, as they have been drawn, rather than coinciding. This must be the case, however, for, considering any two curves, at any particular temperature reading, the pressures for these curves in the receiver are different, while at the thermometer they are the same. The difference of the pressure causing the flow, for any two given curves for any constant temperature, will cause different currents of vapor to flow. That is, the rate of distillation will be different for any two curves for any given temperature reading of the thermometer. Hence the curves cannot coincide. However, since the difference in the pressures in the receiver for any two given consecutive curves is very slight, the curves will nearly coincide, probably more so than shown in the curve sheet.

Any individual curve, as the rate of distillation is decreased, would not theoretically become concave upward and approach the zero point, as shown in the curve sheet, but would follow the general curve until the pressure at the thermometer became equal to the pressure in the receiver—that is, until the difference of pressure causing the flow became zero—when the flow would suddenly cease.

Practically, however, from a consideration of the apparatus, the results can be easily explained. The vapor moves upward past the thermometer, and then its direction is changed and it passes to the condenser. Although the thermometer chamber is covered with heat-resisting materials, a certain amount of vapor will condense on its walls, so that the flow of vapor, as recorded by the liquid passing into the receiver, will be somewhat less than the actual flow past the thermometer. As the flow becomes less, the amount condensed in the thermometer chamber will be an increasing portion of the whole, so that the rate of distillation will become lower very much more rapidly than it theoretically should, but will approach the same zero point.

Curve sheet No. 2 presents a curve showing the relation between vapor pressure and corresponding temperatures for acetophenone, a liquid which was investigated. The full curve was obtained by plotting the receiver pressures as measured against the corresponding lower limiting temperatures as obtained from curve sheet No. 1. The broken line curve was plotted from Kahlbaum.[6]

The extreme lower end of Kahlbaum's curve does not coincide with the one here obtained, but they rapidly come together as the pressures increase. According to the reference given above, Kahlbaum measured his pressures by comparing the height of a mercury column connected with his system with the barometric height, which method cannot be depended on for accurate results at low pressures.

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[6] *Zeitschrift für Physikalische Chemie*, **26**, 603, 1898.

The equation suggested by Biot as a general one for this curve, and which has already been mentioned—that is,

$$\log P = A + Bb^T$$

has been applied to the results here obtained, in combination with Kahlbaum's results. Points on the curve corresponding to pressures of 4, 300, and 760 mm. were used for the determination of the constants. The particular form of the equation as obtained was

$$\log P = 19.696 - 72.540 \times 0.993944^T$$

Vapor Pressure—Temperature Relations for Acetophenone.

TABLE I.

Temperature degree C.	Cbserved P, mm.	Kahlbaum's P, mm.
30	0.391	
31.65	0.444	
34.25	0.492	
36.45	0.583	
37.2	0.679	
39.8	0.844	
42.4	1.030	
44.1	1.157	
46.55	1.278	
48.0	1.370	
49.8	1.546	
54.0	2.055	
57.15	2.520	
60.05	3.112	
63.50	3.800	
65.0		5.0
66.0	4.50	
69.2	5.20	
79.0		10.0
79.7	9.6	
81.2	10.2	
85.4	12.8	
87.4		15.0
87.7	15.4	
92.0	17.7	
93.3		20.0
95.4	21.4	
98.2		25.0
100.3	26.8	
102.3		30.0
106.0		35.0

Values of P were found for corresponding values of T from this equation for various temperatures, and the results are shown in Table II, together with the values of P as obtained from the curve. It will be seen that this equation is an approximation, and not by any means accurate, although the points most liable to show some difference between the calculated and observed values were the ones chosen.

Table II.

Temperature, degrees C.	Observed P, mm.	Calculated P (Biot), mm.	Calculated P (Rankine), mm.
30	0.39	0.44	0.45
50	1.60	1.65	1.705
106	35.0	31.0	32.6
145.1	150.0	146.0	146.3
177.5	400.0	401.0	400.6

"Observed" values of P over 26 mm. of mercury are those given by Kahlbaum.

The equation of Rankine,

$$\log P = A - \frac{B}{T} - \frac{C}{T^2}$$

was also applied to the present case, exactly as was Biot's. With the constants determined, the equation took the form

$$\log P = 16.152 - \frac{3390.96}{T} - \frac{534,192.38}{T^2}$$

Several values of P as found from this equation are found in column 4 of the accompanying Table II. It will be seen that the curve of one equation follows very closely that of the other, and it would be hardly proper to say that either has any advantages over the other, so far as accuracy is concerned, at least in the present case. They are probably equally cumbersome in their manipulation.

It would seem in general, then, from the foregoing, that the actual mathematical representation of the relation between vapor pressures and temperatures, either by means of equations based on theory or by purely empirical forms, has not as yet been satisfactorily accomplished. This relationship appears to be dependent on some phenomenon of which we have, as yet, slight knowledge.

December 12, 1917.

SIR WILLIAM RAMSAY.*

BY

RICHARD B. MOORE,
U. S. Bureau of Mines.

William Ramsay was born in Glasgow, Scotland, October 2, 1852, and died at his country home near London, July 22, 1916. In him the world has lost one of its greatest experimental scientists. A pioneer in most of his work, the results he obtained will undoubtedly be even more appreciated by future generations than by his contemporaries. Whether one accepts all of Ramsay's conclusions or not, there is no one who does not admire the man for his courage and skill, or his work for the new vistas it has opened up and the inspiration it has given.

Ramsay came from scientific stock. His grandfather on his father's side was originally a dyer, but later gave up this business to engage in the manufacture of heavy chemicals used in the dye industry. His uncle, Sir Andrew Crombie Ramsay, was professor of geology in University College, London, and for several years head of the British Geological Survey; while several of his relatives on his mother's side were physicians. Ramsay himself early showed a leaning toward science, especially chemistry. Even before he entered the University of Glasgow he "dabbled" in the science, using small quantities of chemicals furnished by his father.

Ramsay received his early education in the Glasgow Academy, and in 1866 entered the University of Glasgow, at the age of 14. Outside of his early matriculation, he seems to have made no special record at college. In 1869 he received his first real introduction to chemistry when he started work in the laboratory of Robert Tatlock. Later he became Tatlock's assistant, and worked at the same time in physics under William Thomson, who afterward became Lord Kelvin.

Ramsay's ambition was not satisfied with the chemical training he could obtain in Scotland. In 1870 he went to Germany, where, at first, he studied with Bunsen in Heidelberg; but in 1871 he changed to the University of Tübingen, where he worked under Fittig and obtained his Ph.D. degree in 1873. The work he did at this time was on orthotoluic acid and the platinum ammonium compounds. The young chemist returned to Glasgow as assistant in the Young Laboratory of Technical Chemistry, and in 1874 received an appointment as assistant to Prof. John Ferguson, of the University of Glasgow.

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* Communicated by the Author.

He was not content to teach only, but at once started on the investigational work that brought him so much fame. The beginning was modest. His first paper, in 1874, was on a new antimony phosphide with a formula SbP. This was followed in the same year by a short paper on the properties and methods of preparation of hydrogen persulphide. In 1875 he published one paper. This was on the preparation of sodium ethylthiosulphate, and the reaction that takes place when this compound is heated with phosphoric chloride. In the following year he also published one paper—an analysis of a bismuth mineral carrying cobalt and nickel; and in 1877 produced his first paper in physical chemistry on "The Dehydration of Hydrates by the Time Method." Up to this time Ramsay's work showed no promise of what was to come. The problems were simple and were handled in a manner that showed no special ability. In the next few years, however, the young chemist seemed to find himself, and the work which he then did at least laid the foundation for the brilliant discoveries he made later on.

In 1878 and 1879 he published two papers in conjunction with J. J. Dobbie on "The Decomposition Products of Quinine and the Allied Alkaloids." The authors made the important discovery that quinine, quinidine, cinchonine, and cinchonidine, on oxidation, all gave the same acid, and for the first time showed the connection between the alkaloids and pyridine. The work of Kopp on specific volumes had interested Ramsay, and in 1879 he published a paper on "The Specific Volumes of Liquids at Their Boiling-points," which he termed their "ebullition volumes." It occurred to him, during the progress of the work, that some connection might exist between the "ebullition volume" of a liquid and the amount of heat evolved during its formation. In order to ascertain whether such a relation existed, he worked on the heat of formation of aniline, picoline, toluidine, and several other organic compounds, publishing the results in 1879.

In the following year Ramsay received the appointment of professor of chemistry in University College, Bristol, made vacant by the resignation of Doctor Letts. After one year of service he was promoted to the principalship of the college. At the time he was barely 30 years old; the college was still in its infancy, without proper support from the public, whom it was supposed to serve, and had already gone through several strenuous years. Ramsay remained at Bristol until 1887, and not only guided the institution through its many difficulties, but was able, at the same time, to publish a number of important papers. Dr. Sydney Young, his assistant, gave him invaluable service, and several of the papers were published under their joint names. The subjects treated were varied in character, but nearly all were of a physico-chemical nature. The volumes of sodium and phosphorus at their boiling-points were determined; the molecular volumes of some compounds of the benzene, naphthalene, anthracene, and phenanthrene series, and the atomic volume of nitrogen were studied.

Two papers published in the *Proceedings of the Royal Society* on "The Critical State of Gases" and "The Critical Point" led the author to make some very definite statements concerning gases and liquids, and to define the critical point as "that point at which the liquid, owing to expansion, and the gas, owing to compression, acquire the same specific gravity, and consequently are capable of mixing with one another."

In 1884 he published a paper on the halogen compounds of selenium, the work being undertaken in order to compare the stability of the halogen compounds of selenium with those of sulphur by measuring their amount of disassociation, caused by rise of temperature. With Doctor Young, he then studied the decomposition of ammonia by heat, paying special attention to the temperature at which decomposition took place and to the influence of the material of the vessel or tube containing the gas. The author's method of determining the temperatures was crude and novel. It was done by the fusion of salts placed upon small pieces of platinum foil lying on the surface of the tube. If calcium chloride and potassium chloride were used, and if the former salt liquefied, while the latter remained solid, the temperature was taken to be between 719° C. and 734° C. The same two authors showed, in a paper on "The Influence of Pressure on the Temperature of Volatilization of Solids," that solids have definite temperatures of evaporation, corresponding to definite pressures, as liquids have definite boiling-points. "A Method for Obtaining Constant Temperatures" involved using convenient liquids, which could be obtained in a pure condition, and altering the boiling-points of such liquids by changing the pressure to which they were exposed.

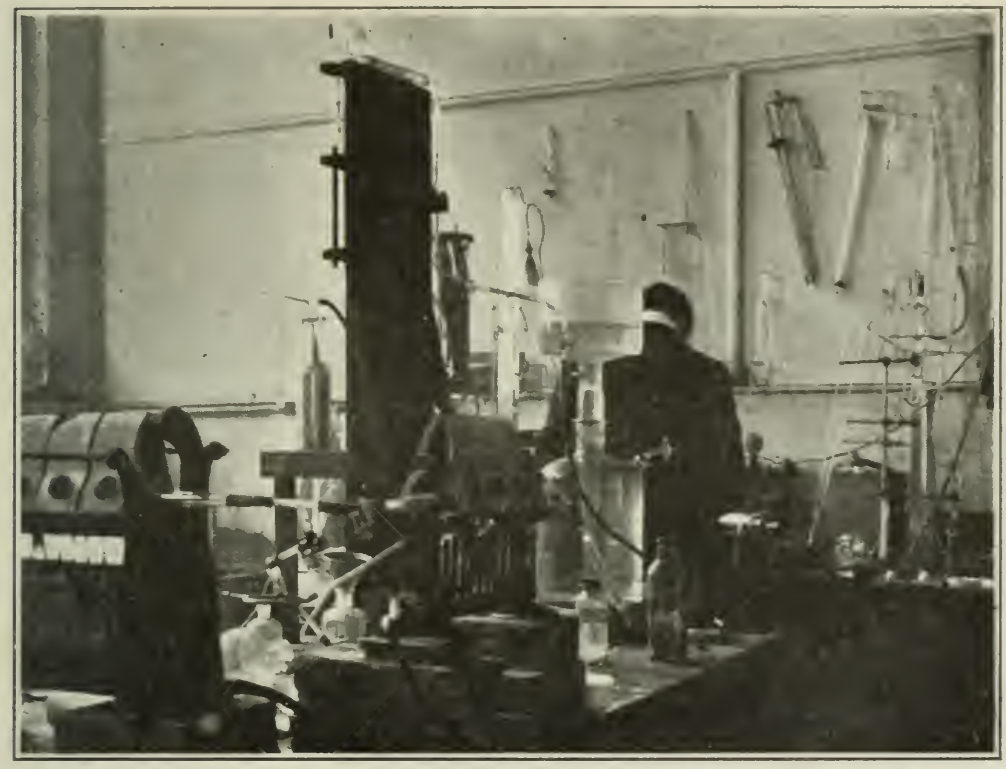
These papers were followed by the publication of a series of vapor pressures, including those of mercury, bromine, iodine, and iodine monochloride, and a controversy with G. W. F. Kahlbaum as to whether Regnault's rule that "with pure substances the curves which show the relation existing between the temperature and pressure of a saturated vapor are identical, whether the method employed in obtaining the data used in their projection be the dynamical or the statical," was or was not true.

During 1886 and 1887 Ramsay and Young published a very considerable number of papers, the majority of them dealing with some phase of work in connection with vapor pressure. In the latter year Ramsay was chosen to succeed Professor Williamson as professor of chemistry at University College, London, and he remained there during the rest of his active professorial life. During the first few years at University College Ramsay worked along the same lines that had won him success at Bristol. It was during this period and the few preceding years that he acquired the training that made his subsequent work on the rare gases possible. He had not only discovered the value of skilful manipulation, but had developed a resourcefulness that stood him in good stead in his later and more important work.

Ramsay very soon got into a new field of chemical research which ultimately changed his reputation from that of a national one to an international one. The work was started through a partly accidental discovery. In 1882, and several succeeding years, Lord Rayleigh worked on the relative density of hydrogen and oxygen. In 1893 he published his results on the densities of some other gases, notably those of oxygen, nitrogen, and air. He prepared the oxygen and nitrogen by different methods; and, while the density of oxygen proved in all cases to be the same, that of nitrogen prepared by chemical methods differed from that of nitrogen obtained from the air. The latter was about 0.5 per cent. heavier than the former. A difference of this magnitude could not be accounted for on the basis of experimental error, and the riddle remained unanswered for some time.

Finally Ramsay asked permission of Lord Rayleigh to take up the matter from a chemical standpoint. He had already in some previous work found that red-hot magnesium was a good absorbent for nitrogen. Hence he concluded that, if there was any part of atmospheric nitrogen different from the rest, a separation might be made by passing the gas over the heated metal.

FIG. 1.



View in Ramsay's laboratory across the centre of the room. On the centre table is shown part of the equipment for removing oxygen and nitrogen from a mixture of rare gases. The glass gas-holder contains partially purified argon, krypton, and xenon.

This was tried, the oxygen first being removed by metallic copper. A slight increase in the density of the product was observed. Arrangements were now made to circulate the gas backward and forward over the heated magnesium. After several days of this treatment the density was found to be 16.1. At this stage Ramsay did not know that he had to deal with a new element, but thought that the results were due to a triatomic form of nitrogen corresponding to ozone. A further absorption by magnesium finally gave a gas with density about 20. It was only when the spectrum of this product was examined that Ramsay became convinced that he had found a new element. Meanwhile Lord Rayleigh was dealing with the problem in a different manner, passing sparks through a mixture of atmospheric nitrogen and oxygen in the presence of sodium hydroxide. The hydroxide absorbed the oxides of nitrogen formed, and, after removal of the excess of oxygen, the resulting gas showed an increase in density. From this point Ramsay and Rayleigh continued the work together, and announced the discovery of the new element at the British Association Meeting in 1894.

It was only natural that such an announcement should meet with a considerable amount of scepticism. All kinds of explanations were offered for the increased density of the gas obtained. It was only after further work had been carried out and the spectrum of the new element definitely established that the doubters were convinced. Since that time Ramsay's share in the discovery has been at times somewhat belittled.

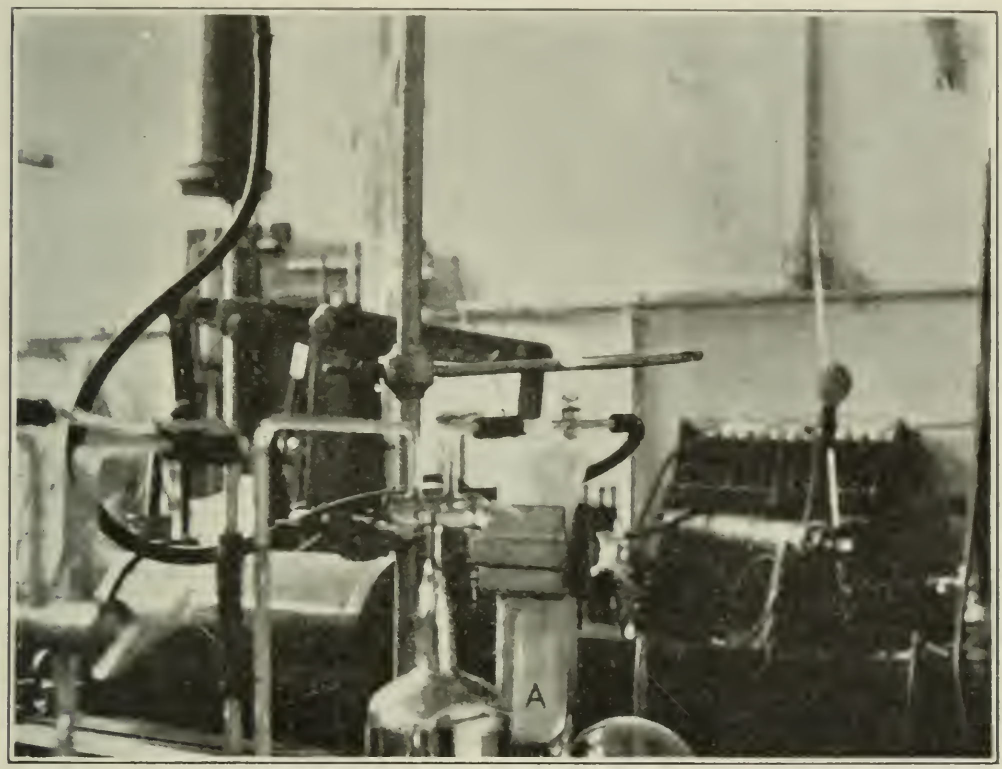
In 1908 the writer was at a dinner in London given to Sir William Ramsay. Lord Rayleigh responded to the principal toast on that occasion, and in his speech most emphatically gave the main share of the credit for the discovery of argon to Ramsay. While this was only just, it goes to show the good feeling which existed between these two notable scientists, and refutes the attempts that were made on several occasions to raise an issue between them.

Ramsay improved on his first method for making argon by using a mixture of lime and magnesium instead of the latter metal alone. The absorption of nitrogen by magnesium is a very slow process, but when mixed with lime the absorption is rapid and complete. The air is first passed over soda-lime and phosphorus pentoxide and then through a tube containing metallic copper, in which the oxygen is absorbed. From this it goes through the magnesium-lime mixture, over heated copper oxide, and finally through other soda-lime and pentoxide tubes. The amount of labor necessary to make argon in quantity by this method is considerable. The copper absorption tube finally used was an iron tube about 6 feet long and nearly 3 inches in diameter. The exhaustion of an apparatus on this scale and reduction of the copper oxide to copper again all involved a great deal of work;

but the final result was 15 litres of argon, which made possible the discovery of some of the other rare gases.

After the discovery of argon Ramsay looked for other sources of the element. He heard, through Sir Henry Miers, of a paper by W. F. Hillebrand, of the United States Geological Survey, in which it was stated that the mineral cleveite, on heating, gave off a considerable quantity of inactive gas, which was supposed to be nitrogen. Ramsay suspected that this gas might be argon, and so obtained a sample of the mineral, heated it with sulphuric acid, pumped off the evolved gas, sparked it with oxygen, and finally ran it into a spectrum tube. The spectrum was entirely different from that of argon, having as a chief characteristic a bright yellow line. According to Ramsay's own account to the writer, his surprise was so great that he at first thought there was something wrong with the spectroscope, and took out his handkerchief and wiped the prism. In addition, others suggested various explanations for the bright yellow line, the most common

Fig. 2.



A near view of a fractionating bulb in Sir William Ramsay's laboratory. The fractionating bulb *A* is immersed in liquid air in a Dewar tube, and the outline of the bulb *A* is indicated by the frozen xenon inside the bulb.

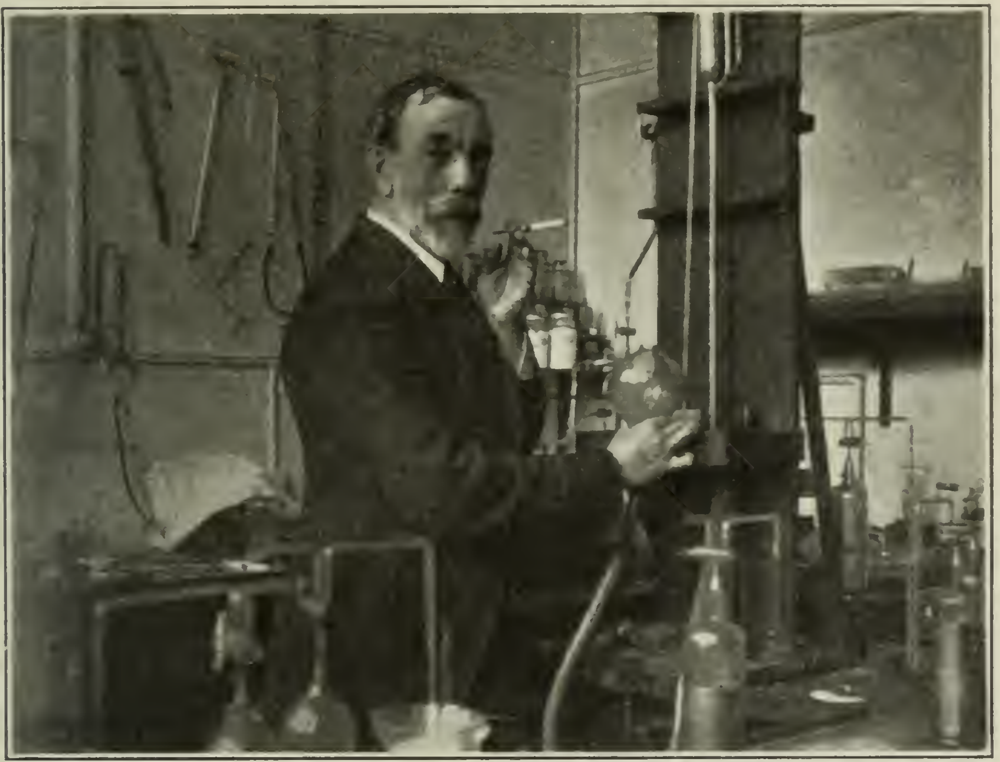
being that it was the sodium line due to dirty electrodes or other causes. It was only when the spectrum of the sodium flame was compared through a comparison prism with the yellow line from the spectrum tube that it became evident beyond question that a new element—namely, terrestrial helium—had been discovered. In 1868 Janssen had noticed this brilliant yellow line in the spectrum of the sun. The name " helium " was given to the element that was responsible for this line by Franklin Lockyer. Sir William Crookes measured the wave-length of the line obtained from the tube first used by Ramsay, and it was found to have a wave-length identical with that of the helium line in the sun. An announcement of the discovery was made at the meeting of the Chemical Society in March, 1895.

It was now probable that other gases besides helium and argon existed. After a large number of minerals had been examined, in addition to the gases from mineral waters, as well as sea-water, which were investigated with the object of finding all possible sources of argon and helium, as well as for new gases, Ramsay, assisted by his pupil, Travers, decided on the fractionation of a considerable quantity of argon. Fifteen litres of the latter gas, as already described, had been prepared, and this was used for the investigation. Before it was fractionated, however, a litre of liquid air presented by Doctor Hampson was allowed to evaporate and the last fraction of gas collected separately. The spectrum of this gas, after purification from nitrogen and oxygen, showed a bright green and a bright yellow line not belonging to the argon spectrum. The density of the sample was also greater than that of argon. The new element was called krypton.

It was natural that with this encouragement the work should be carried on with great eagerness, for there was promise of still more to come. After the discovery of all the gases, and during the examination of their properties, work was continued night and day, only such rest being taken as was absolutely necessary. Such a fruitful field was bound to attract competition; and others, with even a better equipment than Ramsay had, attempted to take advantage of the results of his labor.

With the assistance of Doctor Travers, the 15 litres of argon referred to above was now fractionated. The first fraction which came off, containing the gases with the lowest boiling-points, was separated and examined. The spectrum showed a large number of brilliant red and yellow lines, and the density of this particular sample was about 15. This new gas was called neon. Apparatus was now devised in connection with a Hampson liquid air machine, with which the lighter fractions from liquid air could be reliquefied and refractionated. Finally, a portion was obtained which could not be liquefied even by air, boiling under reduced pressure. This proved to consist largely of neon, but also contained helium—proving the existence of the latter gas in the air. All attempts to separate the helium from the neon were futile, until, later on, the two were fractionated at the temperature of liquid hydrogen. At this temperature the neon solidified and the helium could be pumped off.

FIG. 3.



Photograph of Sir William Ramsay, taken in his laboratory. The Töpler pump, before which he is standing, is the one that he used in all of his rare-gas work.

The residues, or last fractions, from 30 litres of liquid air, which had been allowed to evaporate, were now used to make a larger quantity of krypton. A majority of the gas consisted of argon, which was carried through a rigorous course of fractionation, the last fractions, containing the krypton, showing some new blue lines, with a density greater than that of krypton. After careful refractionation, the final gas obtained gave a density of 64, and the new element was called xenon. The density put this gas in its proper place in the Periodic Table. The volume obtained was only 3 c.c., while the total volume of krypton recovered was 12 c.c. All of the physical constants of these gases were afterward found with the small volumes indicated, and only men possessed of the manipulative skill of Ramsay and Travers could have done this.

The original densities found for these gases were:

Helium	1.98
Neon	9.97
Argon	19.96
Krypton	40.88
Xenon	64

The ratio of specific heat at constant pressure to that at constant volume indicates that all of the gases are monatomic. Their atomic weights, therefore, are:

Helium	3.96
Neon	19.94
Argon	39.92
Krypton	81.76
Xenon	128

Although more recent determinations by some of Ramsay's pupils have changed the atomic weights to some extent, particularly those of krypton and xenon, which are now taken at 92.92 and 130.22, respectively, the original determinations are exceedingly good, considering the conditions under which the work was done.

All attempts made by Ramsay and his pupils to get the rare gases to combine either with each other or with other elements were a failure. Argon was sparked with oxygen, chlorine, and hydrogen. Red-hot sodium hydroxide, sodium peroxide, or fused potassium nitrate had no action. Fluorine, nascent chlorine, and red-hot magnesium were equally ineffective. Helium and the other gases appeared to be as inactive as argon.

The original proportions of the rare gases in the atmosphere determined by Ramsay are, by volume:

Helium	1 part in 245,000
Neon	1 part in 81,000
Argon	1 part in 106.8
Krypton	1 part in 20,000,000
Xenon	1 part in 170,000,000

More recent determinations have modified some of these figures slightly, but it is remarkable that the original determinations were as accurate as they have proved to be.

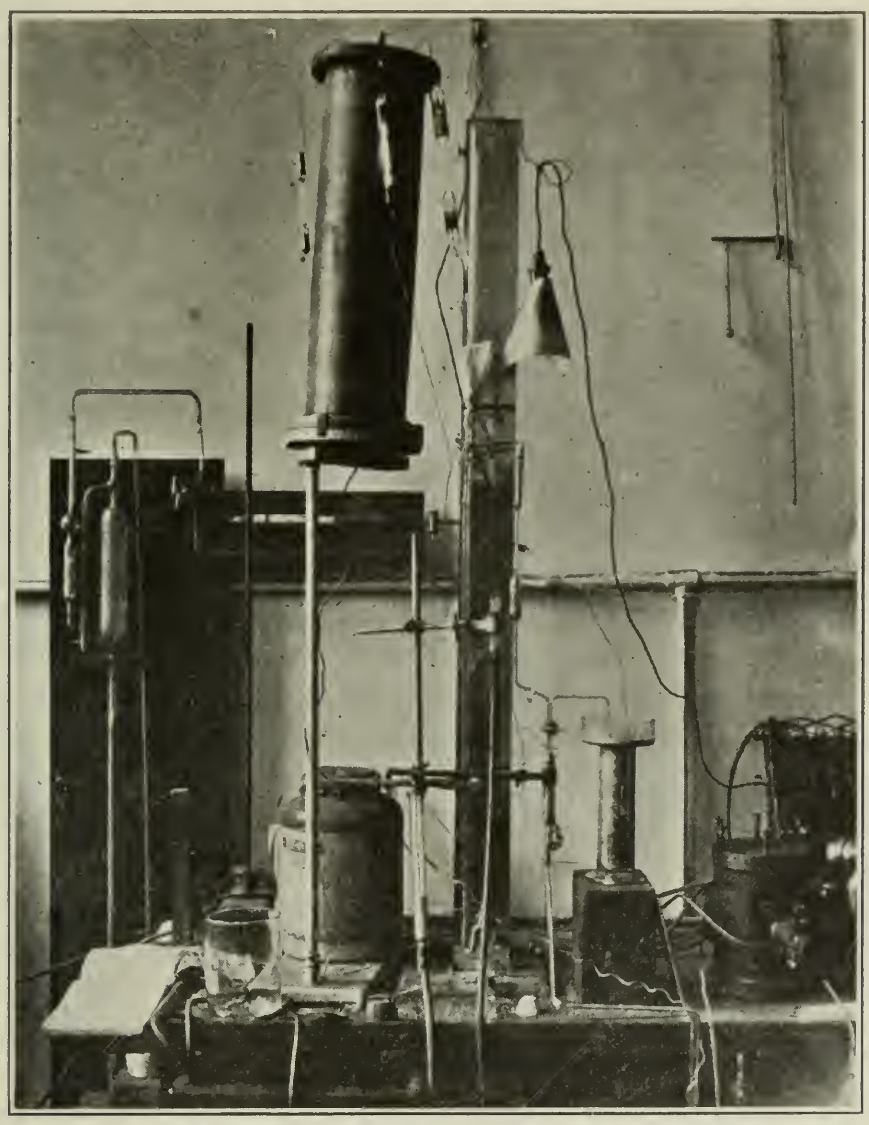
For a number of years Ramsay devoted his attention to other lines of research; further work was done on the rare gases in his laboratory in 1907 and 1908. The probable presence of nebulium in the nebulæ and coronium in the sun made him anxious to investigate more fully the possibility of other rare gases in the atmosphere, either lighter than helium or heavier than xenon. The opportunity came in 1907, when Monsieur Claude, of Paris, offered to furnish a considerable amount of residue obtained in the preparation of oxygen on a large scale by the Claude process. Under the conditions of fractionation of nitrogen from oxygen, the heavier constituents of the atmosphere, such as krypton and xenon, would very largely be left with the liquid oxygen; and, as this oxygen was fractionated off, the residue obtained at the end of any considerable period would retain most of the krypton and xenon and any heavier gas that might be present. One of Ramsay's pupils at first fractionated the residue obtained from 20 tons of liquid air, and the final fractions were examined by the spectrum for new lines without result. As the gases had been subjected to contact with water, there was a possibility of any new gas being dissolved, and hence the work was repeated, using the residue from 100 tons of liquid air, the fractionation being carried out almost entirely without the use of water. The last fraction obtained from the fractionation of the xenon was examined very carefully with the spectroscope, but proved to be pure xenon—no additional lines being present. The result of the work showed that if a new gas, heavier than xenon, existed in the air, it was present in a smaller amount than one part in 2,560,000,000. About 250 c.c. of xenon was obtained in this work, and a slightly smaller amount of krypton, the new material being used for redetermining the densities of the gases. This is the only occasion on which krypton and xenon have ever been prepared in quantity. About the same time Watson worked with Ramsay on the lighter gases, hoping to obtain a gas with smaller density than helium. This search was also unsuccessful, although it resulted in a number of new lines being added to the helium spectrum.

The discovery of radium and its disintegration products opened a new field not only to the physicist, but also to the chemist. The early work was done mainly by physicists, and its progress was therefore hampered for several years. Such a field was bound to be attractive to Ramsay, whose fertile mind quickly saw the possibilities for scientific chemical work in connection with the new science. Doctor Soddy, who had been working with Professor Rutherford in Montreal, came to University College at Ramsay's invitation.

Rutherford had shown that the alpha particle was of a mass comparable to that of the helium atom, and he indicated his belief that the alpha particle actually was a helium atom. Ramsay and Soddy attempted to obtain the spectrum of the radium emanation, and devised an apparatus for handling the very small amount of gas that could be obtained from the radium at his disposal. The emanation was liberated by the solution of the radium salt in water, and, after purification from hydrogen, oxygen, and carbon dioxide, the small volume of resulting gas was run into a capillary tube, a platinum wire acting as one electrode, and the mercury column which confined the gas acting as the other electrode. Owing to slight impurities, they were unable to obtain a spectrum of the emanation, but, on standing, the helium spectrum gradually appeared. This result not only confirmed experimentally Rutherford's theory, but it was the first actual visual proof of the transmutation of one element into another, and gave many scientific men who had been doubting the results obtained by those working in radio-activity the concrete evidence that they desired. This experiment and its result were also something that the public could understand, and added new interest to the remarkable series of discoveries that had already been made in connection with radio-activity. Whereas this first attempt at obtaining the spectrum of the emanation was unsuccessful, later on Ramsay and Collie, working with a larger amount of radium, were successful in a renewed attempt.

The energy given out by radio-active substances, especially those of short life, is enormous. Ramsay argued that if the radio-active substances were changing spontaneously into other elements, the energy available in such changes might be used for transforming other non-radio-active elements into elements of lower atomic weight. With this idea in mind, he started on an investigation which has probably given rise to more discussion than any of his other work. Assisted by his pupil, Mr. A. T. Cameron, he found that if a solution of copper nitrate were

FIG. 4.



A corner of Sir William Ramsay's laboratory. The equipment shown is for the purpose of causing spectrum tubes to glow without actually passing a current between the electrodes.

treated with radium emanation, not only was lithium found in the solution, but the gas which was afterward pumped from the bulb, consisting mostly of hydrogen and oxygen, from the decomposition of the water, after proper purification, gave the argon spectrum, but showed no helium lines. The gas, however, contained 0.34 c.c. of nitrogen. When distilled water was treated with the emanation, neon, with a trace of helium, was obtained, but no argon. The " water-gas " contained 0.307 c.c. of nitrogen. The contention of Ramsay and Cameron was that under certain conditions not only helium but some one of the other rare gases of the atmosphere might constitute one of the disintegration products of the radium emanation. Some experiments of Rutherford afterward proved that the neon from $^1/_{10}$ c.c. of air could be detected under similar conditions. This might be used as an explanation of the presence of neon in the second experiment, but did not explain the absence of helium and also of neon in the first. The nitrogen in both cases was about the same, and, therefore, if this were due to a leak, helium and neon should be recognized in both cases. Madame Curie repeated the work in which lithium was obtained from copper, and reported a negative result. This whole work was left in rather an unsatisfactory condition. The writer asked Ramsay, some time after the above results were published, whether he would repeat them, and received the reply:

" No, I do not think it advisable; I should only find lithium and neon again, and a duplication of results by me would not strengthen the evidence. I shall leave the work to some one else to repeat."

This reply was characteristic of Ramsay's attitude in scientific research. He was more concerned in blazing the trail than in working out details: these he left to others with less imagination and less resourcefulness. During the last few years—thanks to the American carnotite deposits—much more radium is available for such work, and it is to be hoped that some one with the necessary skill and with a much larger amount of radium than Ramsay had in his possession will repeat his work under more ideal conditions. Ramsay's theory was that when an alpha particle struck a non-radio-active atom a glancing blow near the surface the atom was ionized; if it struck the atom squarely in the centre, the latter was broken up with the formation of new elements. Whether this theory will ultimately prove to be correct or not, the work done by Ramsay and Cameron was extremely suggestive and valuable.

At the same time that the above experiments were being carried on, Ramsay and Cameron were investigating the effect of the radium emanation on other chemical reactions. They showed that the emanation decomposed water and caused hydrogen and oxygen to recombine. Hydrochloric acid gave hydrogen and chlorine; mercury absorbed the chlorine, forming a deposit of mercurous chloride. Ammonia was decomposed and the nitrogen and hydrogen of these gases recombined; the amount of recombination (measured by absorbing the ammonia with calcium chloride) was smaller for the same quantity of emanation than the decomposition. Carbon monoxide gave carbon, oxygen, and carbon dioxide. The quantitative results indicated that the amount of chemical action taking place at any time is strictly proportional to the amount of emanation which decays in that time. From this it can be deduced that, other conditions being the same, each atom of emanation as it disintegrates produces a certain definite chemical effect.

In 1910 Ramsay, assisted by Dr. Whytlaw Gray, carried on what was probably the most difficult piece of chemical experimental work ever done. According to the disintegration theory, the radium emanation atom is formed from the radium atom by the elimination of the α particle or helium atom. If radium has an atomic weight of 226 and helium an atomic weight of 4, radium emanation should have, theoretically, an atomic weight of 222. Ramsay and Gray started out to test this theory experimentally. The amount of emanation they had to work with at any given time was not more than 0.005 cu. mm. In order to determine the atomic weight, it was necessary to weigh this minute volume of gas. Fortunately, a suitable balance was at hand in the form of a modification of the Steele and Grant microbalance, which was sensitive to one two-hundred-thousandth of a milligramme. The skill necessary to collect, purify, and weigh the very small volumes of emanation available taxed Ramsay's capabilities probably more than any other piece of work he ever attempted. But the result more than justified the effort. The mean of five determinations gave the atomic weight of the emanation as 223, a striking experimental proof of the theoretical value.

Ramsay carried the enthusiasm which he showed in his scientific work into other lines of endeavor. No matter what he became interested in, he gave his whole heart to the work in hand; and these interests were as broad as they were varied.

He took an active part in the reorganization of the University of London. The old University was an examining body, pure and simple. All that a student had to do was to appear for the examinations and pass them in regular order to obtain his degree. This arrangement did not meet with Ramsay's approval. He felt that, whereas examinations were useful and important, they should not be the chief means of testing a man's ability—hence he threw the whole weight of his influence into the scale for a teaching university, where a man's regular work would count in addition to examinations.

No one knew better than he the value of real productiveness on the part of a student; hence in his own laboratory he encouraged his men to start research work as early as possible, usually in that period of their course that would correspond to the senior year in an American university. In this way the more advanced undergraduates came in direct contact with him and received the benefit of his personal advice and influence, although they always actually worked under instructors or other research students.

Ramsay was an excellent linguist, speaking French and German fluently, and having a knowledge of several other languages. The writer well remembers his interest at times in the Chinese tongue, and, although he never became proficient in this language, the fact that he was willing to put even some time on it shows the interest that he took in matters of this kind. When he gave lectures in France and Germany he was always able to give them in the native tongue of his audience.

One of his chief personal characteristics was his enthusiasm, and this he was able to impart to those around him and to those who worked under him. His students were devoted to him at all times, and the inspiration they received from even a short contact with him was enough to last them a lifetime. It was seldom that he lost patience even with poor work—his plan being to lead and not to drive. Those who "made good" became his friends, and he kept in touch with them long after they had left his immediate influence. His letters always contained references to members of his faculty and students who had left, telling where they had gone and what they were doing. Up to his last years he carried on his heavy correspondence without the aid of a secretary. In a letter, under date of July 23, 1910, he said:

"It is always a pleasure to hear from you. Many thanks for yours of a month ago. My correspondence has grown so formidable that I can hardly keep going; I don't quite know what to do to relieve the strain."

And in another letter he wrote:

"I have been owing you a letter for long. It has sat like a weight on my vitals, and now I am going to disgorge. You have given me an emetic—that is not very complimentary to your letter I fear, but I suppose there *are* pleasant emetics."

His first work at University College for many years was to give a lecture on general chemistry from 9 to 10 in the morning. After this lecture he went to his private laboratory and attended to his correspondence, which often took him until noon. The afternoon was given up to superintending the work of the research men in the laboratory and to actual experimental work on his own part when he did not have affairs of moment outside that called him away.

Ramsay's courage was another great asset. He was never afraid to say or write what he believed to be true, no matter what criticism might be aroused. On one or two occasions he made premature announcements that had to be taken back, but these were few and far between and need not be remembered in connection with the magnificent series of actual discoveries that he gave to the world. It was this quality of courage more than anything else that made him the great man that he was. He had confidence in his own work, and when his results were contrary to those of others he was not afraid to stand by them. On the other hand, he was equally willing to acknowledge a mistake when it was made.

In all of his work he was little interested in details. He was a pioneer in every sense of the word, and after he had beaten out a trail for others to follow he was ever willing to start a new one in some other direction. All of his investigations, especially during the last twenty years of his life, dealt with fundamental problems in chemistry. He was not a great theorist, his work being almost entirely along experimental lines; and when his practical results differed with theory, he was inclined to believe that there was something wrong with the theory. His skill as an experimenter justified this attitude, which was partly responsible for his numerous great discoveries.

Socially he was a charming man, and lacked a great deal of the reserve that Americans associate with most Englishmen. He was full of fun and appreciated at all times a good joke. His home was the scene of many charming entertainments and dinners, and no one knew Ramsay fully who did not see him at his own fireside with his family.

Although a tremendously hard worker, he believed in a reasonable amount of recreation, and usually spent part of either the Christmas or summer vacation in travel. In a letter, written in 1908, he said:

"We have had a very good holiday; first to France, then to Skye, then Clyde, then Dublin, then Inverary, and, lastly, the English Lakes. It looks a century since we left London. Now I have been interviewing students all day. We are in great embarrassment trying to fit 130 people into 100 places. I believe it cannot be done without destruction of life and using the lockers as coffins."

And again, in 1911, he wrote:

"We have just come back, first from Algiers, where we spent a week; next from Paris, where we spent 10 days, being feasted twice a day. It was great fun, and it was delightful meeting such a lot of old friends and making some new ones. Among the latter was Urbain, who is a very strong man. His rare-metal work is admirable. I also saw the fourth Becquerel; his great-grandfather occupied the same laboratory as he does, and he is actually continuing the work of the family, and doing it magnificently—measuring the Zeemann effect on crystals. A lot of work is going on, and the workers are delightfully enthusiastic."

There is no doubt that some of these workers obtained a portion of their enthusiasm from Ramsay himself, even though the personal influence was for only a short time. Ramsay was always interested in public questions of moment, and his opinion was always worth while. He was broad-minded and tried to look at every question from different angles so as to get a proper perspective. At one time, when the liquor question was uppermost in the minds of the English people, he discussed the matter fully with the writer, and proposed a solution that seemed especially applicable to the English problem where high alcoholic beer and stout are consumed instead of whiskey. His suggestion was that a graduated internal revenue tax be put upon liquor of various kinds, such tax being proportionate to the alcoholic content, the tax being increased at a very rapid rate as the alcoholic content increased. In other words, he desired to not only encourage but force the English brewers to make lighter beers similar to those made in Germany, instead of the heavy English ales. He wrote on various timely topics, especially after the war began, when he furnished a series of articles to one of the Manchester papers that dealt with some of the problems that confronted the English nation in an extremely forceful manner. He felt very strongly concerning the unpreparedness of his nation, and did not hesitate to express his opinions where he believed efficiency was lacking. Under date of July 24, 1915, he wrote:

"Things are drifting along, and it appears that the war will be a long one. We are accumulating men and munitions, and there is some talk of forcing the pace before long. You may have heard that I have been doing my level best to stop our 'fools' of ministers from supplying Germany with cotton; it looks as if we were about to succeed at last, but the war would have been over before this if they had done what I asked in January; indeed, they were pressed since September to make cotton contraband."

Again, in another letter of the same year, he said:

"I am also trying to induce our Government to make cotton contraband. In 1913 Germany and Austria imported 670,000 tons of cotton. To-day, so far as conservative estimates can be made, the consumption for war purposes is 350,000 tons a year. If copper is contraband, why not cotton?"

Although no English chemist was more honored by the Germans than Ramsay, there was no English chemist that was more loyal to his country when the break came. Concerning the war, he wrote:

"I have before me your letter of June 11 of last year. What a lot of things have happened since then! I knew Germany meant to attack us, but I thought 1915 would be the year. What I did not know was, first, that they are such brutes; I thought it would be a civilized war; and, second, that their plans would miscarry so hopelessly. We have been awfully lucky—first, in the Belgians delaying the attack, and, second, in our having a Liberal government in power. If the conservatives had been in, the Liberals would have done all in their power to hinder. We were also lucky in Kitchener being available; the conservatives forced the Government to put him at the head of the War Office. Also, we were lucky in having the navy so ready and bottling up theirs. Their recent threat has already come to nothing."

And again:

"You Americans will have to bestir yourselves; are you aware that Germany is organized as a huge trust? You have found that trusts are inconvenient and have legislated against them. What if a nation becomes a trust? The French and Russians are recognizing this, and are considering very drastic measures. A commercial war (for Germany regards commerce as a war, while we look on it as designed for mutual convenience) can only be met by a species of war; and Russia and France are thinking of ostracising Germans and German trade absolutely, buying up all German concerns in Russia and France and excluding all Germans and their goods. The only way of bringing home to Germany the error of their conception of trade is to show them that it will not pay. Well, you will have to consider your position, big as you are; if European markets are closed to Germany and American ones are open, you will have 'dumping' on an immense scale if the Germans can afford it. Indeed, I think you will have a prodigious influx of Germans, for the 'Fatherland' will be a most undesirable place of residence when war is over. The utmost farthing of indemnity will be exacted, and Russia and France will not spare them, whatever we do.

"This letter treats too much of the war, but it is in all our thoughts. You might treat me handsomely and not wait as long as I have done before writing."

In another letter he wrote in the same strain:

"I am glad to see in to-day's papers that President Wilson has made such a 'stiff' answer to the Germans. It appears incredible that you Americans should turn the other cheek to the massacre of a large number of your citizens. But I suppose the German element in the States is strong, and that this informal vote is at the bottom of it. It is one of the disadvantages of a republican government; it is all right in peace, but breaks down in war."

During his last few years Ramsay was engaged on a number of research problems which were either not completed or did not give positive results. Among these was an attempt to synthesize argon from sulphur and hydrogen by means of cathode rays; and the synthesis of krypton from selenium and hydrogen. Also, he investigated the spectrum of radium emanation as it decayed. Some results which he obtained in the action of the radium emanation on thorium nitrate, in which carbon dioxide was always formed, led to an extension of this work to other compounds, such as bismuth and lead perchlorates and chlorates. Ramsay was never held back from trying something on account of the improbability of obtaining a positive result. He never gave up until negative results accumulated sufficiently to prove the futility of further work along the same lines.

After resigning his active work in connection with University College, he retired to a country home, a short distance from London. Concerning this, he wrote:

"We have bought a house about 35 minutes from London by fast train at a little village named Hazlemere, near High Wycomb. The house is ugly but commodious. There are about five acres of ground, mixed wood and meadow, and a capital garden. I am adapting the stage- and coach-house as a laboratory. I doubt if we shall shift before the end of February; the alterations will take some time. We shall have to make our own electricity and gas, but nowadays this is easy.

"I am finding it a great relief not to have these 9 o'clock lectures. I feel as if I were having a perpetual holiday, with plenty to do, but no necessity to do anything at a given moment."

It was here that his last illness seized upon him, and here that he fought his last battle against the dreadful disease that he had done some work to combat during his lifetime. The courage that he showed in his work and in all his undertakings during his lifetime remained with him to the end.

Ramsay received many honors, but none that he did not deserve. He was made a Knight Commander of the Bath, a Knight of the Prussian Order, "Pour le Merìte," an Officer of the Legion of Honor of France, and a Commander of the Crown of Italy. In 1904 he received the Nobel prize in chemistry; in

1895 the Davy Medal of the Royal Society, and in 1897 the Longstaff Medal of the Chemical Society. He was president of the Chemical Society in 1907, and received many honorary degrees from various universities, and was a foreign member of scientific societies in almost every foreign country.

Ramsay was great, not only on account of his scientific discoveries, but on account of his greatness of character, and this greatness was illustrated in no better way than by the service he did to humanity. He gave himself freely, and freely he was rewarded.

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Coal Gas for Motor Traction. W. M. BARRETT. (*The Autocar*, vol. xxxix, No. 1, 148, p. 373, October 20, 1917.)—The restrictions placed by the British Government upon the use of petrol have aroused a great deal of interest during the last few months on the subject of coal gas for motor traction. In the early experiments gas compressed in steel cylinders was used, but, owing to difficulties experienced in reducing the pressure, a flexible gas bag carried on the roof of the vehicle was decided upon. Although many predictions of failure were made, the idea proved practicable and that method of storage soon became very popular. The gas container was made of woven fabric, treated so as to be gas-tight and waterproof. It was circular is shape and held in position on the roof of the vehicle by ropes. It was filled with gas through a flexible sleeve made of the same material as the container itself, and the connection to the engine was made of flexible rubber tube in which a control tap was fitted within easy reach of the driver's hand.

There were many practical disadvantages in using the circular-shaped container, not the least being the tendency of the container when partly deflated to droop over the side of the vehicle, unless the driver took a reef in the ropes every few miles, and the excessive chafing in consequence, to which the container was subject, has a bad effect upon its life. This led to the introduction of the D-shaped container. The bottom of this container is flat and firmly anchored to the superstructure. A further development is the semi-rigid container consisting of a gas-tight box with a flexible top. A development on entirely different lines is the collapsible container, which is made like a concertina, and is guided in its downward travel, as the gas is used up, by flexible stays running on rigid guide rods fixed perpendicularly to the roof of the vehicle, the guide rods being braced at the top to ensure rigidity. The top of the container is weighted with a thin sheet of metal, and as the gas is used up the container folds up and finally lies quite flat.

Much attention has been given to the question of compressing gas at high pressure in steel tanks for traction purposes. The greatest objections to steel cylinders are their weight, risk of accident from breakage while under high pressure, and depreciation of the gas by compression. Among various expedients to meet these objections a cylinder made of a composition of rubber, canvas, and other materials has recently been made by Wood-Milne, Ltd. This cylinder is 4 feet 6 inches long by 1 foot 3 inches in diameter. Weighing 60 pounds uncharged, this container is said to be capable of resisting an internal pressure of 1600 pounds per square inch. At 1000 pounds pressure each cylinder will contain 600 cubic feet of gas (the equivalent of over two gallons of petrol) and weighs, fully charged, less than 100 pounds.

PHYSICS OF THE AIR.*

BY

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CHAPTER XIV (*Continued*).

Thunderstorm Winds.—Shortly, say 20 minutes or so, before the rain of a thunderstorm reaches a given locality the wind at that place, generally light, begins to die down to an approximate calm and to change its direction. At first it usually is from the south or southwest in the northern hemisphere; from the north or northwest in the southern, and in both more or less directly across the path of the storm itself. When the change is complete, it blows for a few minutes, rather gently, directly toward the nearest portion of the storm front, and finally, as the rain is almost at hand, abruptly and in rather violent gusts, away from the storm and, because it has come from above, as will be explained later, in the same direction that the storm is traveling, a direction that, in most cases, differs appreciably from that of the original surface wind. Usually this violent gusty wind lasts through only the earlier portion of the disturbance and then is gradually but rather quickly succeeded by a comparatively gentle wind, that though following the storm at first, frequently, after an hour or so, blows in the same general direction as the original surface wind.

The cause of the thunderstorm winds needs to be carefully considered if one would understand at all clearly the mechanism of the storm itself.

As already explained, this type of storm owes its origin to that vertical convection which results from a more or less superadiabatic temperature gradient. It is this gradient, no matter how established, whether by simple surface heating or by the over and under running of layers of air of widely different temperatures, that permits, or rather forces, the production of the cumulus cloud in which and by the motions of which the electricity that characterizes the thunderstorm is generated.

Nevertheless, as everyone knows, the passage of a cumulus cloud overhead, however large, so long as no rain is falling from it, does not greatly affect the direction and magnitude of the surface wind—does not bring on any of the familiar gusts and other thunderstorm phenomena. Hence, somehow or other, the rain is an important factor, both in starting and in maintaining the winds

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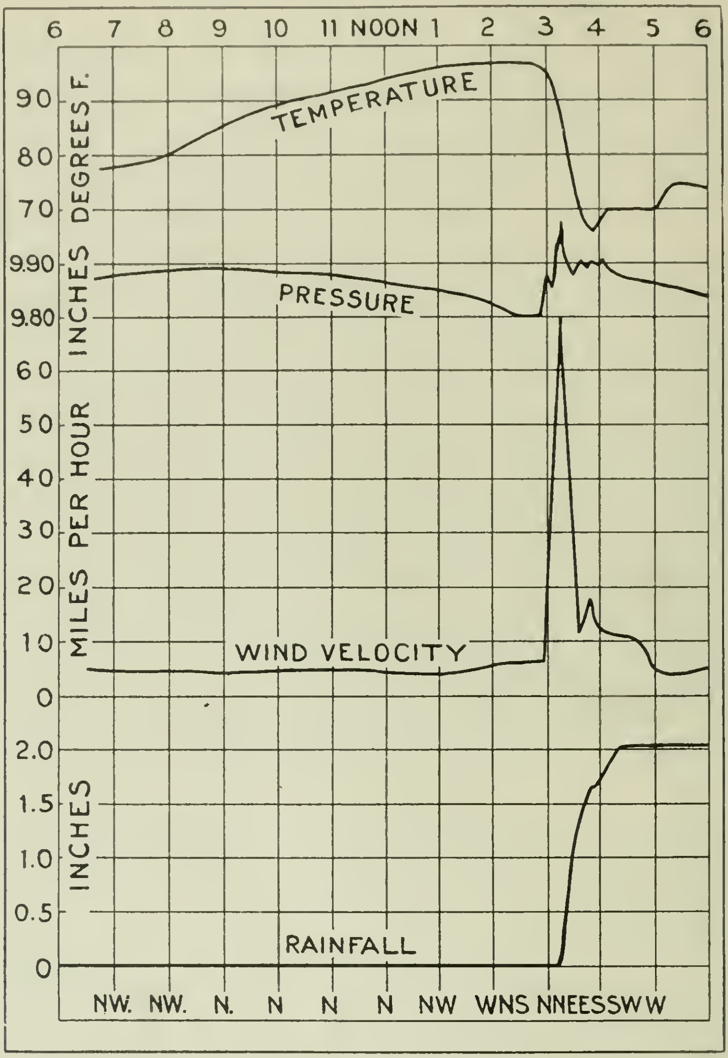
* Continued from page 824, vol. 185, June, 1918.

FIG. 102.



Course of meteorological elements on a thunderstorm day. (Washington, D. C., July 30, 1913.)

in question, for they do not exist before the rain begins nor continue after it has ceased. On the other hand, it cannot be assumed that the rain is the whole cause of these winds, for they do not accompany other and ordinary showers, however heavy the downpour may be.

The actual course of events, illustrated by Fig. 102, taken from the records obtained at Washington, D. C., during the passage of the notable thunder squall of July 30, 1913, seems to be about as follows:

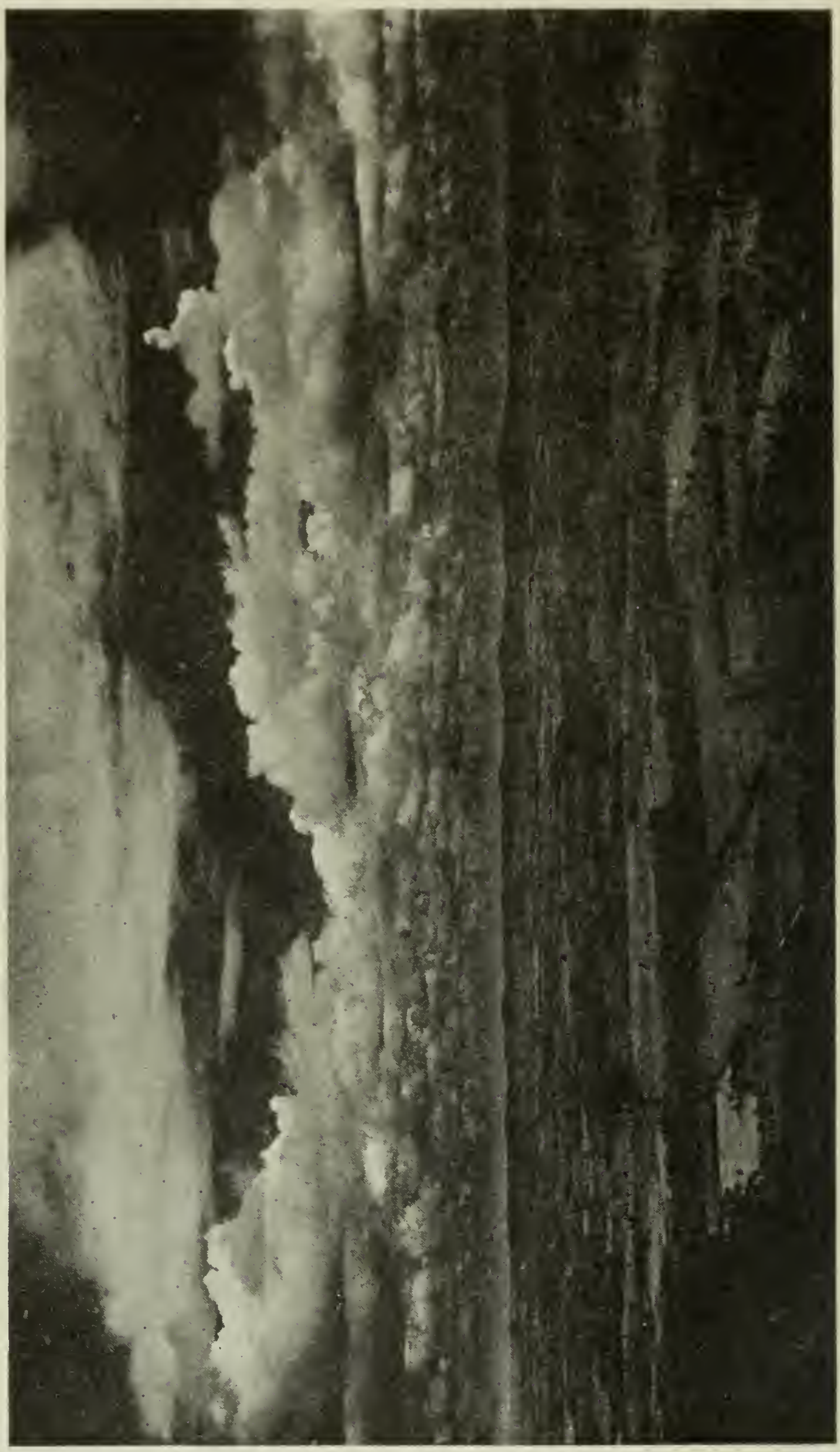
First.—An approximately adiabatic temperature gradient presumably is established over a wide area, roughly up to the base level of the cumulus clouds, all of which, because of a practically common temperature and common humidity over the whole region, must have substantially the same base level and therefore often appear *en échelon,* as shown in Fig. 103. But while the uprising branches of the existing convection currents, due to superadiabatic gradients, may be localized and here and there rather rapid, the return or compensating down-flow is relatively widespread and correspondingly gentle. The condition essential to a local and rapid down-flow, that is, a local decided cooling at a high altitude, does not exist, and therefore the counterpart to the upward current is nowhere conspicuous.

Second.—The convections in the cumuli are accelerated by virtue of the latent heat of vaporization set free in them, and thus one or more of them rapidly developed. In some cases great size and remarkable altitudes are attained, as illustrated by Fig. 104.

Third.—After a time, as a result of the abundant condensation induced by the convectional cooling, rain is formed at a considerable altitude where, of course, the air is quite cold, in fact so cold that often hail is produced. Now this cold rain, or rain and hail, as it falls, and as long as it falls, chills the air from the level of its formation all the way to the earth, partly as a result of its initial low temperature and partly because of the evaporation that takes place during its fall. Hence this continuously chilled column of air, because, partly, of the frictional drag of the rain, but mainly because of the increase, due to this chilling, of its own density, immediately and necessarily becomes a concentrated and vigorous return branch of the vertical circulation. In fact, it (or gravity acting through it) becomes the sustaining cause of the storm's circulation. At the same time, because of the downward blow and because of the retardation of the winds by surface friction, the barometric pressure is abruptly increased, as will be explained later.

It will be worth while to consider some of these statements a little more closely, and to test them with possible numerical values.

FIG. 103.

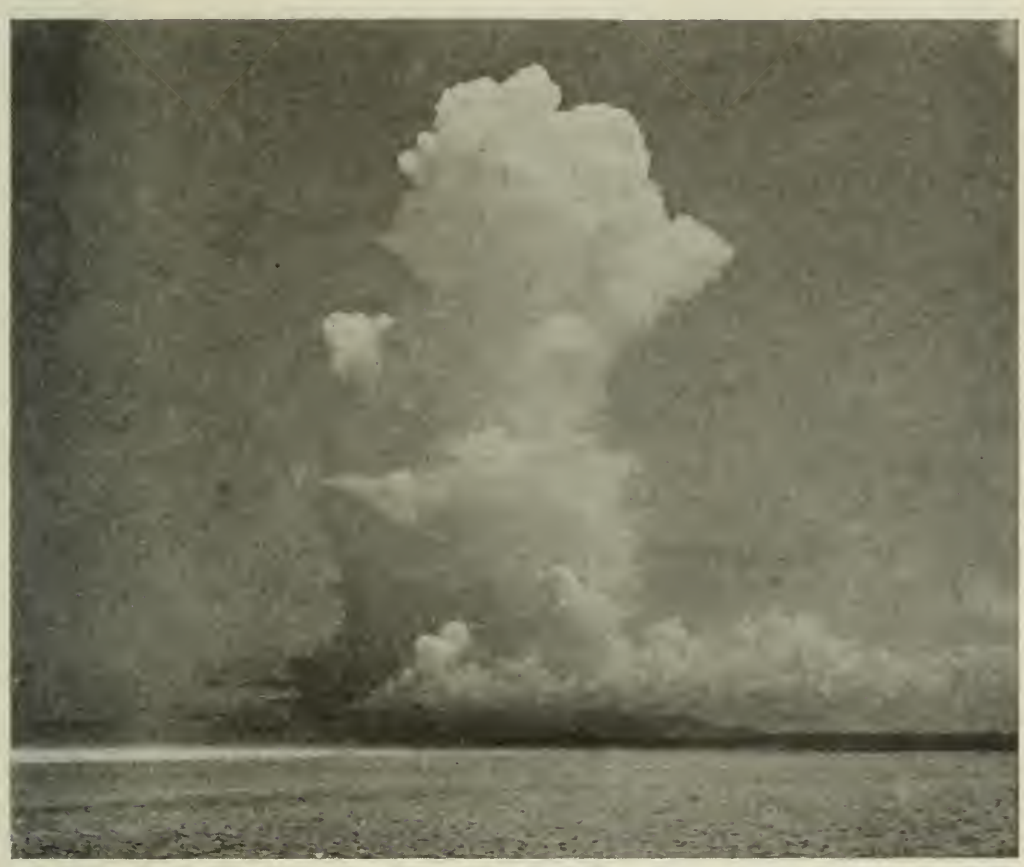


Échelon clouds. (Loudon Valley, Va., E. B. Calvert, photo.)

Omitting, as one may, the effects of radiation, there seem to be but three possible ways by which the cooling of a thunderstorm may be obtained: (*a*) by the descent of originally potentially cold air; (*b*) by chilling the air with the cold rain; (*c*) by evaporation. Each of these will be considered separately.

(*a*) Obviously no portion of the upper air could maintain its position if potentially even slightly colder than that near the surface, that is, so cold that even after warming up adiabatically in a fall to the surface it still would be colder than the air displaced. If at all potentially colder it would fall until it itself became the surface air. Hence the great decrease in temperature that comes with a thunderstorm is not the result of the descent of a layer of air originally potentially cold for, as explained, an upper layer sufficiently cold to give, after its descent, the actual cooling could not exist. Again, any descending air must come from either below the under surface of the cloud or from above this level. If from

FIG. 104.



Towering cumulus. (West end of Java, E. E. Barnard, photo.)

below, then, because of adiabatic heating during its descent through air which, as above explained, has practically the adiabatic temperature gradient, it must reach the earth at substantially the original surface temperature. If from above it would, as is obvious from Fig. 82, reach the earth even warmer than the original surface temperature. Hence, looked at in any way, case *a* clearly is inadmissible.

Possibly the above statements may seem to contravene the explanation that many thunderstorms originate in the establishment by cross currents of superadiabatic temperature gradients. In reality, however, they are in harmony with that explanation which is based on the fact that such gradients can not be maintained, but must at once cause vertical convection. Besides, such mechanically established gradients merely initiate but do not, as we shall see, maintain the storm.

(*b*) Let the under surface of the thunderstorm cloud be 1500 meters above the earth, and the column of air cooled by the cold rain and its evaporation, 2000 meters high. Let the surface temperature be 30° C., and the temperature gradient before the storm begins adiabatic up to the under-cloud level, and let there be a 2-centimeter rainfall.

Now at the temperature assumed, a column of air 2000 meters high whose cross section is 1 square centimeter, and whose base is at sea level, weighs, roughly, 210 grams, and its heat capacity, therefore, is approximately that of 50 grams of water. At the top of this column the temperature can be, at most, only about 20° C. lower than at the bottom, corresponding to the adiabatic or maximum temperature gradient, and if the rain leaves the top at this temperature but reaches the earth 7° C. colder than the surface air before the storm (temperatures that seem at least to be of the correct order), it will have been warmed 13° C. during its fall and the air column, at the expense of whose heat this warming was produced, cooled, on the average, about 0.5° C. But, as a matter of fact, the air usually is cooled from 5° C. to 10° C. Hence, while the temperature of the air necessarily is reduced to some extent by mere heat conduction to the cold rain, much the greater portion of the cooling clearly must have some other origin. Further, since *a* is inadmissible and *b* only a minor contributing factor, it follows by exclusion that of the three obvious causes only evaporation is left to account for much the greater portion of the cooling. Consider, then, whether evaporation really can produce the effects observed.

(*c*) It is a common thing in semiarid regions to see a heavy shower, even a thunder shower, leave the base of a cloud and yet fail utterly to reach the surface of the earth. Hence, it appears quite certain that in the average thunderstorm a considerable portion of the rain that leaves the cloud may evaporate before it reaches the ground, and therefore that the temperature decrease of the atmosphere may largely be owing to this fact. But if so, why then, one properly might ask, does not an equally great temperature drop accompany all heavy rains?

The answer is obvious: It is because, as a rule, the temperature is higher, the relative humidity lower, and the temperature gradient more nearly adiabatic during a thunderstorm than at the time of an ordinary rain. Other rains, those that are accompanied by long horizontal and slow, rather than rapid upward movements of the air, begin only when the humidity is so high that but little evaporation and therefore but little cooling from this source can take place. In such rains there is nothing that can greatly increase the density of the air and consequently there is no rapidly descending current or wind. Thunderstorms, on the other hand, are developed by strong vertical convection which establishes a nearly adiabatic gradient and when the relative humidity, in the case of the heat thunderstorm, at least, is low, 50 per cent., say, evaporation into this air, as soon as the rain has begun, obviously must be rapid, with the consequent cooling and increase of density correspondingly great. Hence, since the temperature gradient was already nearly adiabatic, a strong downward current necessarily is established in the midst of the falling and evaporating rain. Further, whatever the type of thunderstorm, the descending air, which can be no more than saturated at the base of the cloud, dynamically warms so rapidly that evaporation into it can not keep pace with its water capacity. That is, evaporation which takes place all the way from cloud to earth, by rendering the air locally cool and dense, causes it to fall, while this fall, in turn, through dynamical heating, maintains the evaporation. Hence the downrush of the air must continue so long as there is an abundant supply of local rain, and cease when the rain becomes light.

It will be instructive now to return to the numerical values and compute a probable magnitude of the cooling due to evaporation.

As before, let a 2-centimeter rain leave the cloud, but let one-fourth of the rain that started, or half a centimeter, be evaporated. This would consume 303 heat units from an air column 2000 meters high whose heat capacity is that of only 50 cubic centimeters of water. Hence, as a result of evaporation alone, the temperature of the air column would be lowered on the average by about 6° C. Evaporation, therefore, appears to be both necessary and sufficient to produce all or nearly all the cooling of a thunderstorm.

But what is the effect of this evaporation on the density of the atmosphere? Since the molecular weight of water is 18 while the average molecular weight of air is approximately 29, it follows that the amount of evaporation above assumed would decrease the density of the atmosphere by, roughly, one part in a thousand. On the other hand, a decrease in temperature of 6° C., that would be produced by the evaporation assumed, would increase it by about one part in fifty. Hence the resultant of these two opposing effects is substantially that of the second alone; that is, a distinct increase in density, and a consequent downrush of cold air.

Doubtless, as already implied, the evaporation of thunderstorm rain, and therefore the drop in temperature and the consequent fractional gain in density, all increase with decrease of elevation. In some measure, however, this effect is counteracted by the higher temperatures of the lower layers—the higher the absolute temperature the less proportionately the change of density per degree change of temperature. But no matter how nor to what extent the details may vary, it seems quite certain that the cold rain of a thunderstorm and its evaporation together must establish a local downrush of cold air, an observed important and characteristic phenomena, really the immediate cause of the vigorous circulation, whose rational explanation has been attempted in the past few paragraphs.

As the column or sheet of cold air flows down it maintains in great measure its original horizontal velocity and, therefore, on reaching the earth rushes forward in the direction of the storm movement, underrunning and buoying up the adjacent warm air. And this condition, largely due, as explained, to condensation and evaporation, once established, necessarily is self-perpetuating, so long as the general temperature gradient, humidity, and wind direction are favorable. It must be remembered, however, that thunderstorm convection, rising air just in front and descending air with the rain, does not occur in a closed circuit, for the air that goes up does not return nor does the air that comes down immediately go up again, there simply is an interchange between the surface air in front of the storm and the upper air in its rear. The travel of the storm, by keeping up with the underunning cold current, just as effectually maintains the temperature contrasts essential to this open-circuit convection as does continuous heating on one side and cooling on the other maintain the temperature contrast essential to a closed circuit convection.

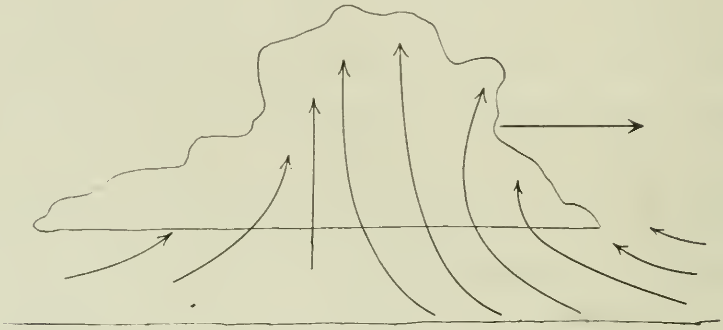
The movements of the warm air in front of the rain, the lull, the inflow, and the updraft, resemble somewhat those of a horizontal cylinder resting on the earth where the air is quiet and rolling forward with the speed of the storm. Similarly, the cold air in its descent and forward rush, together with the updraft of warm air, also resembles a horizontal cylinder, but one sliding on the earth and turning in the opposite direction from that of the forward-rolling or all-warm cylinder. In neither case, however, is the analogy complete, for, as above explained, the air that goes up remains aloft, while the cold air that comes down is kept by its greater density to the lower levels. The condition of flow persists, as do cataracts and crestclouds (clouds along mountain crests), but here, too, as in their case, the material involved is ever renewed.

The Squall Cloud.—Between the uprising sheet of warm air and the adjacent descending sheet of cold air horizontal vortices are sure to be formed in which the two currents are more or less mixed. The lower of these vortices can only be *inferred* as a necessary consequence of the opposite directions of flow of the adjacent sheets of warm and cold air, for there is nothing to render them visible. Neither can any vortices that may exist within the cloud be seen. Near the front lower edge of the cumulo-nimbus system, however, and immediately in front of the sheet of rain, or rain and hail, the rising air has so nearly reached its dew point that the somewhat lower temperature produced by the admixture of the descending cold air is sufficient to produce in it a light fog-like condensation which, of course, renders any detached vortex at this position quite visible.

This squall cloud, in which the direction of motion on top is against the storm, may be regarded as a third horizontal thunderstorm cylinder much smaller but more complete than either of the others.

Schematic Illustrations.—The above conceptions of the mechanism of a thunderstorm can, perhaps, be made a little clearer with the aid of illustrations. Fig. 105, a schematic representation of a thunderstorm in the making, gives the boundary of a large cumulus cloud from which rain has not yet begun to fall, and the stream lines of atmospheric flow into it. When the cloud is stationary and there is no surface wind the updraft obviously will be more or less symmetrical about a vertical through its centre, but when it has an appreciable velocity, as indicated in the figure, it is equally obvious that most, often nearly all, of the air entering the cloud will do so through its front under-surface. At this stage there will be no concentrated or local down current, only counter settling of the air round about, because, as previously explained, the air cataract requires strong local cooling, and this, in turn, calls for local rain.

FIG. 105.



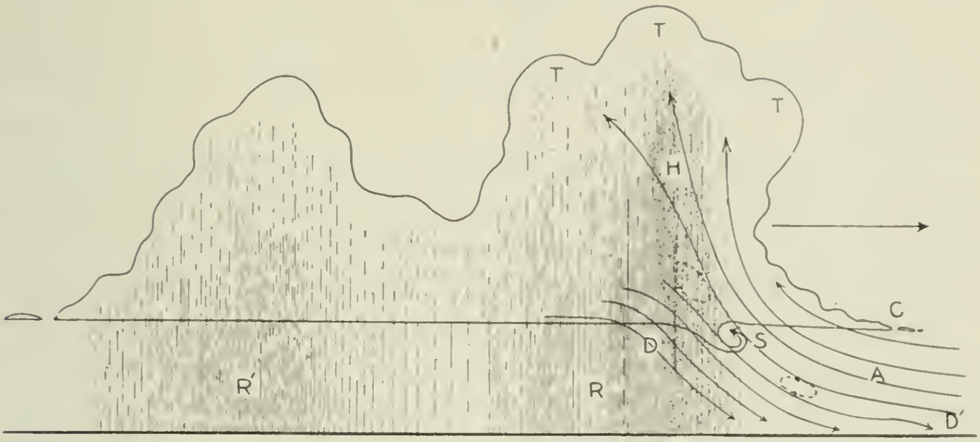
Principal air movements in the development of a cumulus cloud.

Fig. 106 schematically represents a well-developed thunderstorm in progress. The rain, often mixed with hail, cools the air through which it falls, both by conduction and evaporation, the hail also by fusion, and as the temperature gradient over a considerable area already was closely adiabatic it follows that the actual temperatures within the rain column must be lower than those of the surrounding air at corresponding levels all the way from the surface of the earth to within the cloud, that is, throughout and a little beyond the nonsaturated or evaporating region.

As soon, then, as this column or sheet of air is sufficiently cooled it flows down and forward and all the atmospheric movements peculiar to the thunderstorm are established substantially as represented.

Referring to the figure: The warm ascending air is in the region *A*; the cold descending air at *D*; the dust cloud (in dry weather) at *D′*; the squall cloud at *S*; the storm collar at *C*; the thunder heads at *T*; the hail at *H*; the primary rain, due to initial convection, at *R*; and the secondary rain at *R′*. This latter phenomenon, the secondary rain, is a thing of frequent occurrence and often is due, as indicated in the figure, to the coalescence and quiet settling of drops from an abandoned portion of the cumulus in which and below which winds and convection are no longer active.

FIG. 106.



Ideal cross-section of a typical thunderstorm. *A*, ascending air; *D*, descending air; *C*, storm collar; *S*, roll scud; *D′*, wind gust; *H*, hail; *T*, thunderheads; *R*, primary rain; *R′*, secondary rain.

The thunderstorm is also frequently accompanied by false cirri, occasionally by scarf clouds and even, though rarely, by mamato-cumuli; but, as none of these is essential to it, all, therefore, are omitted from the above schematic illustration.

Thunderstorm Pressures.—Before the onset of a thunderstorm there usually if not always is a distinct fall in the barometer. At times this fall is extended over several hours, but whether the period be long or short the rate of fall usually is greatest at the near approach of the storm. Just as the storm breaks, however, the pressure rises very rapidly, usually from 1 to 2 millimeters, fluctuates irregularly, and finally, as the storm passes, again becomes rather steady but at a somewhat higher pressure than prevailed before the rain began.

The cause of these pressure changes is rather complex. The decrease in the absolute water vapor of the air as a whole, measured by the condensation, and the decrease in the temperature of the lower air—perhaps more than offset by the latent heat set free in the upper—both tend to increase the atmospheric pressure, and each contributes its share to the final result. Both these effects, however, are comparatively permanent, and while they may be mainly responsible for the increase of pressure after the storm has gone by, they probably are not the chief factors in the production of the initial and quickly produced pressure maximum. Here at least two factors, one obvious, the other inconspicuous, are involved. These are: (*a*) the rapid downrush of air, and (*b*) the interference to horizontal flow caused by the vertical circulation.

The downrush of air clearly produces a vertically directed pressure on the surface of the earth, in the same manner that a horizontal flow produces a horizontally directed pressure against the side of a house. But a pressure equal to that given by 2 mm. of mercury, a pressure increase frequently reached in a thunderstorm, would mean about 2.72 grams per square centimeter, or 27.2 kilograms per square meter, and require a wind velocity of, roughly, 50 kilometers per hour or 14 meters per second. Now, the velocity of the downrush of air in a thunderstorm is not at all accurately known, but while at times probably very considerable, the above value of 14 meters per second seems to be excessive; in fact, its average value may not be even half so great. If in reality it is not, then, since the pressure of a wind varies as the square of its velocity, it follows that less than one-fourth of the actual pressure increase can be caused in this way. Hence it would seem that there probably is at least one other pressure factor, and, indeed, such a factor obviously exists in the check to the horizontal flow caused by vertical convection.

To make this point clear: Assume two layers of air, an upper and a lower, flowing parallel to each other. Let their respective masses per unit length in the direction of their horizontal movement be M and m, and their velocities V and v. Now, if, through convection, say, the whole or any portion of the lower layer is carried aloft, it must be replaced below by an equal amount of the upper air.

Let the whole of the lower layer be carried up. To produce the rainfall above assumed, 2 centimeters, this layer would have to be at least 1 kilometer deep; but no matter what its depth if it should merely change places with the upper air, there obviously could be no effect on the flow nor on the height of the barometer. Even if the different layers should mingle and assume a common velocity V', the rate of flow would still remain unchanged, in accordance with the law of the conservation of linear momentum, and the barometer reading unaltered.

In symbols we would have the equation

$$MV + mv = (M + m)\ V'.$$

Hence neither interchange nor mingling of the two air currents, upper and lower, can change the vertical mass of the atmosphere, nor, therefore, the surface pressure. But, then, in the case of atmospheric convection there is something more than simple mingling of two air currents, and the linear momentum does not, in general, remain constant. The increased surface velocity following convection, a phenomenon very marked in the case of a thunderstorm, causes an increased frictional drag and therefore a greater or less decrease in the total flow. Suppose this amounts to the equivalent of reducing the velocity of a layer of air only 25 meters thick from V to v, and let $V = 5v$. That is, the equivalent of the one-three-hundred-and-twentieth part of the atmosphere having its flow reduced to one-fifth its former value. This would reduce the total flow of the atmosphere by about 1 part in 400, and thereby increase the barometric reading by nearly 2 millimeters.

It would seem, then, that the friction of the thunderstorm gust on the surface of the earth, through the consequent decrease in the total linear momentum of the atmosphere and, therefore, its total flow, must be an important contributing cause of the rapid and marked increase of the barometric pressure that accompanies the onset of a heavy thunderstorm.

To sum up: The chief factors contributing to the increase of the barometric pressure during a thunderstorm appear to be, possibly in the order of their magnitude: (*a*) decrease of horizontal flow, due to surface friction; (*b*) vertical wind pressure, due to descending air; (*c*) decrease in total humidity, due to precipitation; (*d*) lower temperature, due largely to evaporation—probably more than offset by the heat of condensation.

Thunderstorm Temperatures.—Before the onset of the storm the temperature commonly is high, but it begins rapidly to fall with the first outward gust and soon drops often as much as 5° C. to 10° C., because, as already explained, this gust is a portion of the descending air cooled by the cold rain and by its evaporation. As the storm passes the temperature generally recovers somewhat, though it seldom regains its original value.

Thunderstorm Humidity.—As previously explained, heavy rain, at least up in the clouds, and therefore much humidity, and a temperature contrast sufficient to produce rapid vertical convection, are essential to the genesis of a thunderstorm. Hence during the early forenoon of a day favorable to the development of heat thunderstorms both the absolute and relative humidity are likely to be high. Just before the storm, however, when the temperature has greatly increased, though the absolute humidity still is high, the relative humidity is likely to be rather low. On the other hand, during and immediately after the storm, the relative humidity is high, owing to both evaporation and decrease of temperature, and a little later, at least, the absolute humidity, because of the removal of a large amount of moisture from the atmosphere, often, presumably, comparatively low.

"Rain-gush."—It has frequently been noted that the rainfall is greatest after heavy claps of thunder, a fact that appears to have given much comfort and great encouragement to those who maintain the efficacy of mere noise to produce precipitation—to jostle cloud particles together into raindrops. The correct explanation, however, of this phenomenon seems obvious: The violent turmoil and spasmodic movements within a large cumulus or thunderstorm cloud cause similar irregularities in the condensation and resulting number of raindrops at any given level. These in turn, as broken by the air currents, give local excess of electrification and of electric discharge or lightning flash. We have, then, starting toward the earth at the same time and from practically the same level, mass, sound, and light. The light travels with the greatest velocity, about 300,000 kilometers per second, and therefore the lightning flash is seen before the thunder is heard—its velocity being, roughly, only 330 meters per second—while the

rain, with a maximum velocity of 8 to 10 meters per second with reference to the air, reaches the earth still later. In fact, it is the excessive condensation or rain formation up in the cumulus cloud that causes the vivid lightning and the heavy thunder. According only to the order in which their several velocities cause them to reach the surface of the earth it might appear, and has often been so interpreted, that lightning, the first perceived, is the cause of thunder, which, indeed, it is, and that heavy thunder, the next in order, is the cause of excessive rain, which most certainly it is not.

Thunderstorm Velocity.—The velocity of the thunderstorm is simply the velocity of the atmosphere in which the bulk of the cumulus cloud happens to be located. Hence, as the wind at this level is faster by night than by day and faster over the ocean than over land, it follows that exactly the same relations hold for the thunderstorm, namely, that it travels faster over water than over land and faster by night than by day. The actual velocity of the thunderstorm, of course, varies greatly, but its average velocity in Europe is 30 to 50 kilometers per hour; in the United States, 50 to 65 kilometers per hour.

Hail.—Hail, consisting of lumps of roughly concentric layers of compact snow and solid ice, is a conspicuous and well-known phenomenon that occurs during the early portion of most severe extratropical thunderstorms. But in what portion of the cloud it is formed and by what process the layers of ice and snow are built up are facts that, far from being obvious, become clear only when the mechanism of the storm itself is understood.

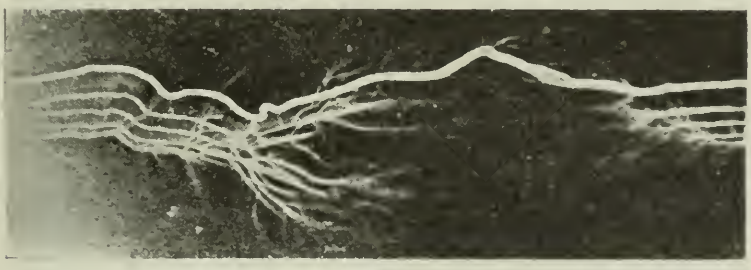
As before, let the surface temperature be 30° C. and the absolute humidity 50 per cent., or the dew point 18° C. nearly. Under these conditions saturation will obtain, and, therefore, cloud formation begin when the surface air has risen to an elevation of approximately 1.5 kilometers. Immediately above this level the latent heat of condensation reduces the rate of temperature decrease with elevation to about half its former value, nor does this rate rapidly increase with further gain of height. Hence in mid-latitudes, where the above assumptions correspond in general to average thunderstorm conditions, it is only beyond the 4-kilometer level that freezing temperatures are reached, and where hail, therefore, can form. In the tropics and, after mid-summer, in the warmer portions of the temperate regions, where the freezing level is very high, hail seldom occurs. Generally, either it is not formed at all, owing to insufficient cloud height, or, if formed, is melted before reaching the ground from its initial great altitude.

The process by which the nucleus of the hailstone is formed and its layer upon layer of snow and ice built up seems to be as follows: Such drops of rain as the strong updraft within the cloud blows into the region of freezing temperatures quickly congeal and also gather coatings of snow and frost. After a time each incipient hailstone gets into a weaker updraft, for this is always irregular and puffy, or else tumbles to the edge of the ascending column. In either case it then falls back into the region of liquid drops where it gathers a layer of water, a portion of which is at once frozen by the low temperature of the kernel. But again it meets an upward gust, or falls back where the ascending draft is stronger, and again the cyclic journey from realm of rain to region of snow is begun; and each time—there may be several—the journey is completed a new layer of ice and fresh layer of snow are added. In general the size of the hailstones will be roughly proportional to the strength of the convection current, but since their weights vary approximately (they are not homogeneous) as the cubes of their diameters, while the supporting force of the upward air current varies, also approximately, as only the square of their diameters, it follows that a limiting size is quickly reached. It is also evident, from the fact that a strong convection current is essential to the formation of hail, that it can occur only where this convection exists; that is, in the *front* portion of a heavy to violent thunderstorm.

Some meteorologists hold that the roll scud between the ascending warm and descending cold air is the seat of hail formation, but this is a mistaken assumption. Centrifugal force would throw a solid object, like a hailstone, out of this roll probably before a single turn had been completed. Besides, and this objection is, perhaps, more obviously fatal than the one just given, the temperature of the roll scud, because of its position, the lowest of the whole storm cloud, clearly must be many degrees above the freezing point. Indeed, as the above calculation shows, temperatures low enough for the formation of hail can not often obtain at levels much less than three times that of the scud, and therefore it evidently is in the higher levels of the cumulus and not in the low scud that hail must have its genesis and make its growth.

Lightning.—About the middle of the eighteenth century Franklin and others clearly demonstrated that the lightning of a thunderstorm and the discharge of an ordinary electric machine are identical in nature, and thereby established the fact that many of the properties of the former may logically be inferred from laboratory experiments with the latter. There is, however, one important difference between the two phenomena that does not seem always to be kept in mind, namely, the distribution of the charge. In the one case, that of the laboratory experiment, the charge commonly exists almost wholly on the surface of the apparatus used, while in the other, that of the thunderstorm, it is irregularly distributed throughout the great cloud volume. Hence the two discharges, lightning and laboratory sparks, necessarily differ from each other in important details. Nevertheless, in each case the atmosphere must be ionized before the discharge can take place freely, and this condition seems, at times at least, to establish itself progresso-spasmodically. That is, a small initial discharge, losing itself in a terminal brush, is rapidly followed by another and another, each losing itself in a manner similar to the first, until a path from pole to pole is sufficiently ionized to permit of a free electric flow and quick exhaustion of the remaining charge. Fig. 107, copied from a photograph by Walter[96], taken on a rapidly moving plate, shows how a laboratory spark spasmodically (doubtless influenced by the period of electrical oscillation) ionizes the air from either pole and thus progressively extends and finally closes the conducting path of complete discharge. There appears also to be good evidence that the lightning discharge often behaves in a manner generally similiar, though, perhaps, radically

FIG. 107.



Growth of an electric spark discharge. (Walter.)

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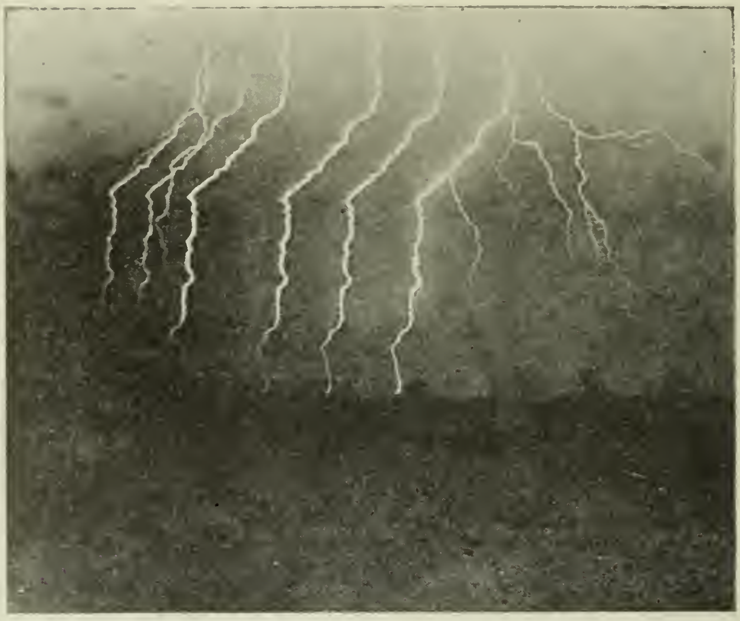
[96] *Annalen der Physik u. Chemie, Leipzig*, 1899, **68**, 776.

different, in certain details. Thus the free period of electrical oscillation that belongs to ordinary laboratory apparatus presumably affects the process of discharge building as well as the nature of the discharge after it is fully established; while, on the other hand, if, as seems practically certain, lightning is not oscillatory, it follows that its growth into a full flash must be acquired by some process independent of a periodic surge.

Lightning, however, usually is pulsatory, as is obvious from the flicker of sheet lightning, described below, discharge after discharge taking place in the same direction and along the same path. Occasionally these sequent discharges extend to unequal distances, the latter especially becoming feebler and shorter, as shown in Fig. 108, thereby in their decay inversely simulating the growth or progressive development of a freely oscillating laboratory discharge. However, being pulsatory, or consisting of a group of unidirectional discharges, is an entirely different thing from being oscillatory, that is, consisting of an equally spaced series the units of which are alternately in opposite directions.

FIG. 108



Streak lightning (sequent discharges), rotating camera. (Larsen.)

It will be convenient, in further discussing the facts known about lightning, to classify it according to its general appearance.

Streak Lightning.—When the storm is close by, the lightning discharge invariaby appears to the unaided eye as one or more sinuous lines or streaks of vivid white or pink—invariably sinuous, because electrically the atmosphere is always heterogeneous or unequally ionized and the directive force constantly changing during, and because of, the discharge itself. Often there is one main trunk with a number of branches, all occurring at the same time and apparently instantaneously, while at other times there are two or more simultaneous though locally disconnected streaks. Frequently the discharge continues flickeringly (on rare occasions even steady, like a white-hot wire) during a perceptible time—occasionally a full second.

But all these phenomena are best studied by means of the camera, and have been so studied by several persons, among whom Walter, of Hamburg; Larsén, of Chicago; and Steadworthy, of Toronto, are among the most persistent and successful. Stationary cameras, revolving cameras, stereoscopic cameras, cameras with revolving plates, and cameras with spectrographic attachments have all been used, separately and jointly, and the results have abundantly justified the time and the labor devoted to the work.

(*To be continued.*)

The Corrosion of Fence Wire. O. W. STOREY. (*Proceedings of the American Electrochemical Society,* October 3–6, 1917.)—The short life of present-day fence wire as compared with the older wires, some of which are still in service, has been the source of considerable trouble to the users of this product. A study of the analyses of a large number of fence wires has resulted in the conclusion that the presence of a sufficient amount of copper in steel wire determines whether that wire is resistant to corrosion. The results have without exception shown that where two steel wires have been subjected to identical corroding conditions the wire with an appreciable percentage of copper has shown the lesser corrosion. In the light of recent extensive investigations on the corrosion of iron and steel, especially copper steels, these results, covering a period of twenty to thirty years or more, are of much significance, in that they confirm the results obtained in corrosion tests covering a short period of time.

It has been definitely established that the durability of old steel fence wire is due to the presence of copper; present-day steel fence wire usually does not contain copper, and therefore corrodes rapidly. Manganese does not increase the corrosion of steel, and its absence does not decrease the corrosion. Steel fence wire containing copper is as durable as wrought iron. The copper in the early steels and wrought irons came from the copper-bearing ores of the eastern United States and imported ores. The proportion of copper-steel made decreased with the increasing importance of the copper-free Lake Superior ores.

The life of fence wire is dependent upon the quality of both the galvanizing and the iron or steel base. Since the galvanizing is usually thin, the life of the fence depends principally upon the iron or steel base, which should be highly resistant to corrosion. Under ordinary atmospheric conditions, zinc corrodes more slowly when other conditions favor rapid corrosion of iron, and, *vice versa,* iron corrodes more slowly when conditions favor the rapid corrosion of zinc.

Railway Electrification as a Means of Saving Fuel. E. W. RICE, JR. (*General Electrical Review,* vol. 21, No. 3, p. 171, March, 1918.)—Where electricity has been substituted for steam in the operation of railroads, fully 50 per cent. increase in available capacity of existing tracks and other facilities has been demonstrated. This increased capacity has been due to a variety of causes, but largely to the increased reliability and capacity of electric locomotives under all conditions of service, thus permitting a speeding up of train schedules by some 25 per cent. under average conditions.

It is estimated that something like 150,000,000 tons of coal were consumed by the railroads in the year 1917. It is now known, from the results from such electrical operation of railroads as we already have in this country, that it would be possible to save at least two-thirds of this coal if electric locomotives were substituted for the present steam locomotives. On this basis there would be a saving of over 100,000,000 tons of coal in one year. This is an amount three times as large as the total coal exported from the United States during 1917. The carrying capacity of our steam roads is also seriously restricted by the movement of coal required for the haulage of the trains themselves. Estimates indicate that fully 10 per cent. of the total ton-mileage movement behind the engine drawbar is made up of company coal and coal cars, including in this connection the steam-engine tender and its contents. The consumption of fuel oil by railroads is also very great, 40,000,000 barrels, it is said, having been used in 1913, or nearly 15 per cent. of the total oil produced.

The possible use of water power should also be considered. According to estimates, there are not less than 25,000,000 horsepower of water power available in the United States, and if this were developed and could be used in operating our railroads, each horsepower so used would save at least 6 pounds of coal now burned under the boilers of our steam locomotives. It is true that this water power is not uniformly distributed in the districts where the railroad requirements are greatest, but the possibilities indicated by the figures are so impressive that they justify careful examination as to the extent to which water power could be so employed and the amount of coal that could be saved by its use.

PRESENTATION OF THE FRANKLIN MEDAL.

MAY 15, 1918.

At the Stated Meeting of the Committee on Science and the Arts, held April 3, 1918, the following resolutions were adopted:

"*Resolved*, That The Franklin Medal be awarded to Guglielmo Marconi, Electrical Engineer, of Italy, in recognition of his brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors."

"*Resolved*, That The Franklin Medal be awarded to Thomas Corwin Mendenhall, Physicist, of Ravenna, Ohio, in recognition of his fruitful and indefatigable labors in physical research, particularly his contributions to our knowledge of physical constants and electrical standards."

CORRESPONDENCE WITH MEDALLISTS.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

Signor Guglielmo Marconi, April 8, 1918.
Italian Senate,
Rome, Italy.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Guglielmo Marconi, Electrical Engineer, of Italy, for his brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors."

The medal, and accompanying certificate are being prepared and His Excellency, Count V. Macchi de Cellere, your Government's Minister at Washington, has been requested to come to the Institute on Wednesday, May 15, to receive this medal and certificate on your behalf.

I am,
Respectfully,
(Signed) GEO. A. HOADLEY,
Acting Secretary.

GAH:W

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

Count V. Macchi de Cellere,
Ambassador Extraordinary and
Plenipotentiary of His Majesty
the King of Italy.

APRIL 8, 1918.

SIR:

I have the honour to inform you that The Franklin Institute has awarded to Signor Guglielmo Marconi, Italian Senate, Rome, Italy, The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications.

The award is minuted as follows:

> "That The Franklin Medal be awarded to Guglielmo Marconi, Electrical Engineer, of Italy, for his brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you, representing your Government, a cordial invitation to come to the Institute on Wednesday, May 15th, to receive this medal and certificate from our President, for Signor Marconi.

Two Franklin Medals have been awarded this year, one to Signor Marconi, and one to Dr. T. C. Mendenhall, Physicist, of Ravenna, Ohio, U. S. A.

An invitation will be extended to you and to Doctor Mendenhall to be the guests of honour at a dinner following the presentation ceremonies. These invitations will be formally sent you at a later date by the President of the Institute, Dr. Walton Clark.

I am,
Your Excellency's very humble servant,
(Signed) GEO. A. HOADLEY,
Acting Secretary.

GAH:W

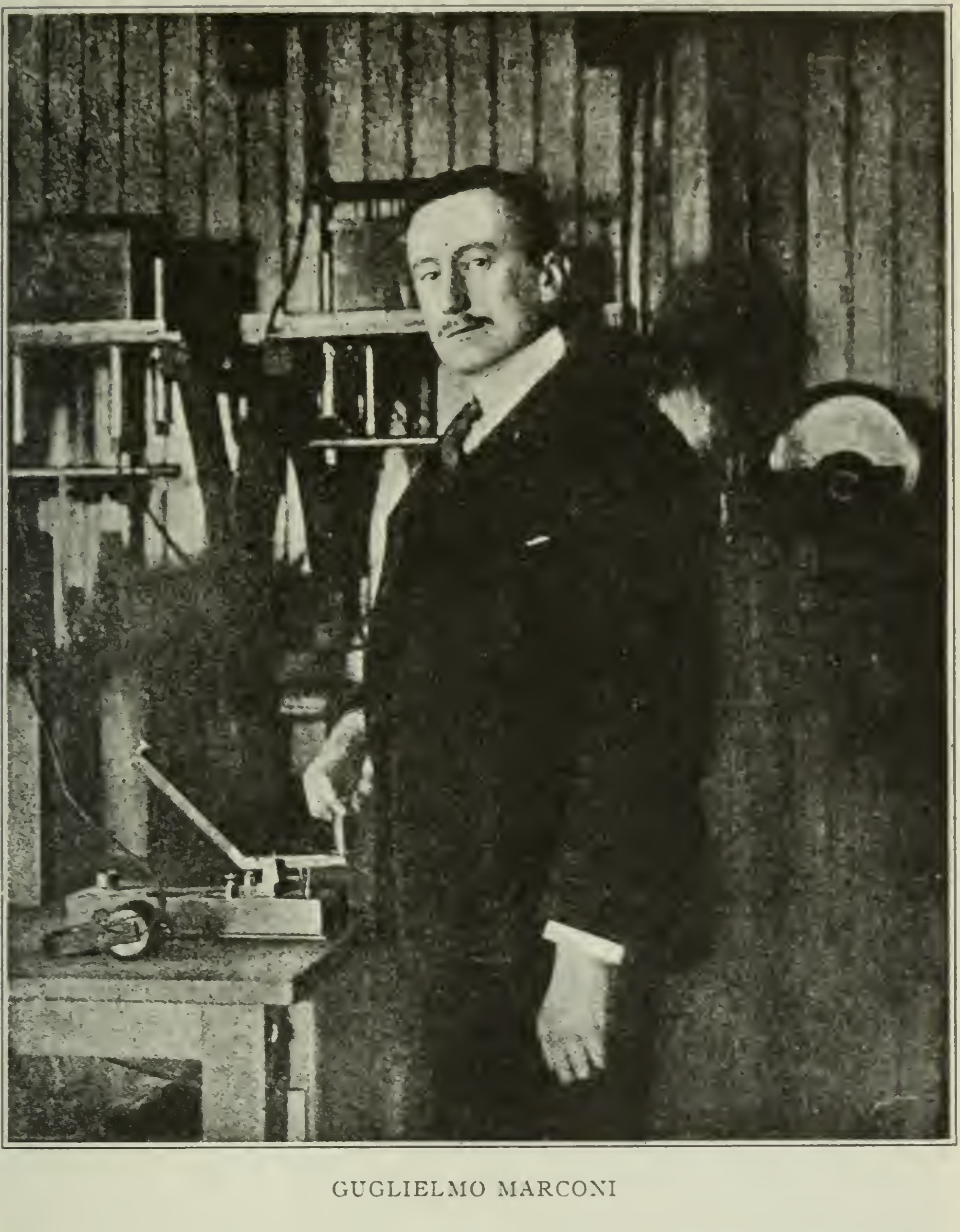
THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

APRIL 6, 1918.

Dr. Thomas C. Mendenhall,
Ravenna,
Ohio.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in



GUGLIELMO MARCONI

physical science or technology, without regard to country, whose efforts in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Thomas C. Mendenhall, Physicist, of Ravenna, Ohio, for his fruitful and indefatigable labors in physical research, particularly his contributions to our knowledge of physical constants and electrical standards."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on Wednesday, May 15th, to receive this medal and certificate from our President.

I am,
Respectfully,
(Signed) GEO. A. HOADLEY,
Acting Secretary.

GAH:W

REGIA AMBASCIATE D'ITALIA

WASHINGTON, April 11, 1918.

DEAR SIR:

I have learned with the greatest pleasure by your letter of the 8th instant, that The Franklin Institute has deliberated to award to Senator Marconi The Franklin Medal in recognition of his contribution to scientific attainments, and I know that every Italian will rejoice with me and feel proud of the honor thus bestowed upon our illustrious fellow-citizen.

This expression of my appreciation I beg you to accept and to convey to the Board of The Franklin Institute.

As for the invitation extended to me to come to the Institute on Wednesday, May 15th, to receive this medal from your President on behalf of Senator Marconi, I count it as an honor and would accept it without reservations, should the duties of my office allow me to do so. In fact, I am not able to state, with such anticipation, whether at the last moment I will be free to come. But, assuring you that I would feel happy to come, I can say that, were this impossible to me, I would send a representative to act in my stead.

May I now ask you whether The Franklin Institute has already communicated directly to Senator Marconi the honor of this distinction, or whether they think it preferable to make the communication through me? If so, I would be pleased with such a task.

I am, Sir, with best regards,
Very truly yours,
(Signed) MACCHI DE CELLERE,
Italian Ambassador.

GEORGE A. HOADLEY, ESQ.,
ACTING SECRETARY OF THE FRANKLIN INSTITUTE

THOMAS CORWIN MENDENHALL

COSMOS CLUB

WASHINGTON, D. C., April 19, 1918.

MY DEAR MR. HOADLEY:

Yours of the 6th instant has just reached me, having been forwarded from Ravenna.

I cannot tell you how surprised I am and how gratified by your notice of the action of The Franklin Institute in awarding me The Franklin Medal. It is an honor which if one may not covet, one may fully enjoy and appreciate when it comes, even though it seems beyond one's deserts. I know of nothing at present that will stand in the way of my being at the meeting of May 15th.

I am staying here until after the meeting of the National Academy of Sciences, which will be concluded two weeks from to-day. As only first-class mail is being forwarded to me, if you have an extra copy of the reprint from the Journal referring to the presentation of the medal in 1917, and will send it to me here, I will be greatly obliged.

As ever,

Yours faithfully,

(Signed) T. C. MENDENHALL.

MR. GEO. A. HOADLEY,
ACTING SECRETARY,
FRANKLIN INSTITUTE,
Philadelphia, Pa.

CABLEGRAM.

ROME, Italy, May 25, 1918.

George Hoadley,
Franklin Institute,
Philadelphia.

Please convey to Board of Franklin Institute my deep appreciation of the great honour they have conferred upon me by the award of The Franklin Medal.

GUGLIELMO MARCONI.

PROGRAMME OF MEETING, MAY 15, 1918.

Presentation of The Franklin Medal to Count V. Macchi de Cellere, on behalf of the Royal Italian Government, for Senator Guglielmo Marconi.

Presentation of The Franklin Medal to Thomas Corwin Mendenhall, Sc.D., LL.D.

Address by Doctor Mendenhall—"Some Metrological Memories."

PRESENTATION OF THE FRANKLIN MEDAL TO SENATOR GUGLIELMO MARCONI AND DOCTOR THOMAS CORWIN MENDENHALL.

IN calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievement, and recognized Dr. Harry F. Keller, who made the following statement relative to the work of Senator Marconi:

Mr. President: The May meeting of the Institute for the presentation of the Franklin Medal has come to be regarded as one of the red letter days on the calendar of this venerable scientific society. It is the occasion of our gathering here to do honor and pay our tribute to "those workers in physical science and technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance our knowledge of physical science and its applications," and it is your privilege as President to present to them or to their accredited representatives the highest award within the gift of the Institute.

Heretofore the Committee on Science and the Arts has deemed it expedient to restrict its choice of medallists to men of science who were citizens of countries not actively engaged in the great European war. It is true that when these medals were presented by you in 1917 our country had committed herself to this great conflict for human rights and liberty, and more than a month had passed since our President and Congress had declared that a state of war existed between the United States and the German Empire. But the committee's recommendations as to the choice of medallists had then been made and ratified by the Institute, and there being no reason to reconsider them, but rather every reason in their favor, the presentation of the medals was proceeded with.

This year, of course, your committee approached its task under totally different conditions. The declaration of war had absolutely changed our relations towards the subject of peace and war, and so in considering the awards your committee was actuated by the desire and determination that its choice should fall upon men only whose achievements had unmistakably and materially contributed to the welfare of our Nation and that of its Allies. It is with full confidence that this aim has been realized that I now have the honor, on behalf of the Committee of Science and the Arts, to present to you our distinguished guests who are to receive from you these beautiful medals.

Of the two medallists the first belongs to a nation which, inspired by the same ideals of liberty and democracy that compelled our country to enter the great conflict, and which after several years of almost superhuman resistance against the enemy, and untold sacrifices in blood and treasure, is now our associate in arms; the other an American scientist whose career has been devoted largely to the service of the Nation, and the fruits of whose work are now seen in many departments of the scientific and engineering activities conducted by our government.

Mr. President: The Italian inventor whose achievements the Institute desires to recognize by the award of The Franklin Medal is of that brilliant type of workers who concentrate their endeavors upon a single great problem, or rather series of problems, in applied science. It is with his name that we associate an epoch-making achievement, the invention of wireless telegraphy and its successful development into a universal system of communication.

The story of how this marvellous invention came to be made and how, by successive steps, it has been perfected into a commercial and transoceanic system has been so often and well told that I may take it for granted that this audience is quite familiar with this romance of scientific achievement. In common with other great inventors the creator of the wireless art has not been spared the experience of unjust and ungenerous attacks upon his claims by envious rivals and competitors. Those who know him personally describe him as of a modest and even retiring disposition, but the results of his labors have spoken for him so eloquently that his title to the inventions in question is now beyond the shadow of a doubt. He is universally acclaimed as an electrical engineer and inventor of the foremost rank whose achievements stand out preëminently by their international character and significance. It is to them that Italy owes the renewal of the glory in electrical science conferred upon her by the fundamental discoveries of Galvani and Volta.

Our medallist was born at Bologna April 25, 1874. On his father's side he is of purely Italian stock, but his mother was a native of Ireland. After receiving his elementary education at Leghorn he attended the University of Bologna, where he pursued scientific studies. As early as 1890 he conducted experiments to prove that electric currents can be made to pass through any medium, and that once started they will follow their course without deviation and without the aid of a conductor. A device constructed by him in 1896 for sending signals without the use of wires attracted the attention of Sir William Preece, who tested it with most encouraging results in England. The new method of sending messages was based upon the use of electric waves, the existence of which was first suggested by Clerk Maxwell and, later, experimentally verified by H. Hertz, who also succeeded in measuring their velocities and wave lengths. As I need hardly explain to you, these waves are set up by an oscillatory spark (such as that of a Leiden jar) and travel through the ether, just as light waves do, differing from the latter only in wave length. They can be received and detected at a distance by a spark gap similar to that of the transmitter. A better way, however, of detecting them was found in what is known as the *coherer*, which is a glass tube filled with metallic filings. An ordinary current will not readily pass through such particles, owing to the resistance of their loose contacts, but when the electric waves fall upon them they cohere or cling together, making the filings a conductor. Upon tapping the tube the resistance is restored. During the first ten years, when the art was still in its infancy, the method of sending and receiving wireless messages consisted essentially in the application of these principles. In 1905 our medallist devised his directive system of wireless telegraphy, and in the following year a new persistent-wave system of wireless service. Since then both the apparatus and the practice of this art have been greatly improved.

At the present time the essential features of a wireless system are briefly these: At the transmitting station is an induction coil or transformer, the secondary of which charges a condenser to the potential at which the spark discharge passes across the gap. The frequency of the oscillations is regulated by the operator with the aid of sliding contacts. The spark then induces oscillations in the aerial-wire system (the wires of the latter being stretched (horizontally), tuned to resonance with a second sliding contact. Now the electric waves sent out by this system induce oscillations in the aerial of the receiving station, which may be thousands of miles away, and this aerial is also tuned to resonance by means of a variable capacity and an "inductance." The detector is a crystal of carborundum placed in series with a telephone receiver. The carborundum allows the intermittent current to pass in one direction only while the oscillations of a given spark continue, and then to cease until those of the next spark arrive. The operator hears a musical note corresponding to the frequency of the sparks as long as the key is depressed. Long and short notes represent the dots and dashes of ordinary telegraphy. To prevent the receiver from picking up waves of other periods a series of tuned circuits are inserted before the detector.

I shall not tire you with a detailed explanation of the apparatus and its working, as these may be found by reference to any up-to-date text on physics or electricity.*

The first successful tests of the wireless method were made in England, between Penarth and Weston, and a little later by the Italian Ministry of Marine at Spezia. In 1899 wireless communication was established across the English Channel, and in the same year the inventor came to this country, using his method in the following year to report the election. The epoch-making experiments of sending wireless messages across the Atlantic from Poldhu, Cornwall, to St. John's, New Foundland, were made in 1901, and regular wireless communication across the Atlantic was established in the following year, the formal inauguratory message being transmitted by the Governor-General of Canada to the King of England. Among other spectacular incidents in the development of the wireless system I may mention the message from the President of the United States to the

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* For a very complete account see "The Principles of Electric Wave Telegraphy and Telephony," by J. A. Fleming, London, Longmans, Green and Co.

King of England, opening the wireless service from Cape Cod, Mass., to Cornwall; the voyage of the cruiser *Carlo Alberto* from England to Kronstadt Harbor in 1902, during which messages were continuously received on board of the ship from the Cornwall station; a similar trip of H. M. S. *Duncan* from Portsmouth to Gibraltar in 1903; and of the Cunard Liner *Campania*, Liverpool to New York, in 1904, when the wireless service supplied the news to the first ocean daily newspaper, the *Cunard Daily Bulletin.* In 1907 the commercial service between England and America was established. Since then the method of wireless telegraphy has been adopted in one form or another by practically all countries and made use of in every part of the globe. It may be truly said of it that it has revolutionized our means of communication, and annihilated distance on land, on the sea and in the air.

That the wizard who has made these dreams of the scientist a reality has been honored in every conceivable way goes without saying. Universities and learned societies in all parts of the world have showered upon him their degrees and medals; in 1909 he shared with the physicist Ferdinand Braun the Nobel prize in physics, and many high distinctions and orders have been conferred upon him both at home and abroad.

Although it is but a short time since Senator Guglielmo Marconi was here on a most important mission from his government, the award of The Franklin Medal to him must be made *in absentia.* But as in the case of former presentations of it to foreign scientists we are honored to-day by the presence of the official representative of the medallist's country. He has graciously consented to come here from Washington and to receive on behalf of his government, for Senator Marconi, The Franklin Medal. Mr. President, I have the honor to present to you the Italian Ambassador, his Excellency Count V. Macchi de Cellere.

The President in presenting The Franklin Medal to Count Cellere said:

Your Excellency: I have the honor, in the name of The Franklin Institute, upon recommendation of its Committee on Science and the Arts, to present to you The Franklin Medal and Diploma for transmission to Senator Marconi through the State Department of your August Sovereign, the King of Italy. This award to your distinguished countryman is in recognition of his signal services rendered to humanity in the field of science. It is the highest honor in the gift of the Institute.

In accepting the medal for Senator Marconi Count Cellere said:

Honorable Members of the Institute: I am recipient to-day of a medal which, while destined to one of Italy's greatest sons, is an homage to Italy herself. The honor of accepting this homage in the name of Guglielmo Marconi fills me with pride, both as an Italian and a friend of the scientist whose achievements have far transcended the limits of space and time. The mysterious ways of Nature have been harnessed by him to serve the purpose of men—and the glory of the inventor has been confided to the faithful, everlasting reverence of mankind, for whom wireless telegraphy has become not only a miraculous means of communication, but also one of the greatest aids to progress and defense.

As in most cases of inventions which have been of supreme benefit to men, this one, due to the genius of a son of Italy, has meant to the inventor long years of assiduous work. It has been, in fact, the result of that combination of genius and perseverance that has given to the world the system of Galileo, the electric battery of Volta and the vision of Benjamin Franklin.

This is not a casual association of names. It is the evidence of Marconi's greatness, and of the place that Italy, thanks to her most gifted sons, has held and holds among the Nations illustrious for scientific achievements beneficial to mankind.

This medal which you, Members of this learned Institute, have conferred upon Guglielmo Marconi, will always remind him of the admiration you, men of science, and all of us, have for him.

In accepting it in his name, I thank you, gentlemen. May the friendship that unites this great Republic and Italy be as lasting as the metal in which the name of our inventor is indelibly engraved. May the glory of our two friendly Nations shine for ever, and the genius of our men hereafter be devoted entirely to the peaceful labors which alone can give mankind that high degree of civilization that has been the ideal of all past generations and must become the reality of the present one.

In introducing Doctor Mendenhall, Doctor Keller said:

Mr. President: The second medallist, as already stated, is a compatriot of ours. Advanced in years, yet vigorous as ever of body and mind, he has made the long journey from Ravenna, Ohio, to receive from you The Franklin Medal and to tell us something from the rich store of experiences he has gathered in his long and successful scientific career. He is a typical American in that he found and created his own opportunities and indefatigably always gave the best that was in him to serve his fellows and his country. Born at Hanoverton, Ohio, October 4, 1841, he received his early education in the public schools, and acquired his scientific training without attending any prescribed courses in a college or university. When only thirty-two years of age he was called to the chair of physics and mechanics in the Ohio State University, and such was the distinction he achieved during the five years of his incumbency that, in 1878, he received and accepted a call from the Imperial University of Japan, at Tokio, where he remained until 1881. In recognition of his services as professor of physics at this institution he was subsequently decorated with the order of the Sacred Treasures by the Japanese Government, and also awarded the gold medal of the National Educational Society of Japan. Returning to the Ohio State University he continued in the chair of physics until 1884, when he was made emeritus professor. In the meantime his achievements as a scientist, engineer and educator had attracted attention in many quarters. From 1884–1886 he was professor in the United States Signal Corps, and in the latter year he was elected to the Presidency of the Rose Polytechnic Institute, which position he left in 1889 to assume the duties of Superintendent of the United States Coast and Geodetic Survey. After five years of successful and distinguished service in that capacity he was President of the Worcester Polytechnic Institute from 1894 until 1901. In addition to the many and exacting duties which these several positions imposed upon him he also gave freely of his time and energy to work as a member of many important commissions of the National Government, and it is indeed to the invaluable contributions which he made to the labors of these bodies that his fame as a scientist and engineer is largely due. Thus he served as Superintendent of the United States Bureau of Weights and Measures from 1889–1894, and during these years also he was a member of the United States Lighthouse Board, of the first Bering Sea Commission and of the United States and Great Britain Boundary Commission. In 1893 he was the delegate of the United States to the Electrical Congress. Among the historical relics preserved and treasured in this Institute is a little document, the rough draft by the hand of our medallist of the definitions and specifications of the fundamental electrical units, the Ohm, the Ampère, and the Volt. The manuscript shows that only a few slight changes were made in the definitions as drafted by him before they were adopted and signed by the representatives of the countries that participated in the Congress. He is now the sole survivor of the distinguished group, which also included E. Mascart, v. Helmholtz, W. E. Ayrton, and H. A. Rowland.

In the brief time allotted to me I shall not attempt even to sketch the contributions our medallist has made to physical science and its applications. A mere enumeration of them would tax your patience. Suffice it to say that the principal problems that have come within the range of his labors are in the fields of terrestrial gravity, seismology, atmospheric electricity, electrical measurements and standards, and spectroscopy. For his geographical and physical investigation of Alaska he received the gold medal of the American Geographical Society, and a gold medal at the Paris Exposition of 1900 for papers upon technical education.

I cannot conclude these remarks without a brief reference to our medallist's literary productions. Besides a fine appreciation of the late Professor Henry A. Rowland they include a number of highly interesting and valuable essays, mostly in popular language, on physical and engineering subjects, recording past achievements and discussing problems of the future.

And it seems to me that it is this transition from old-time natural philosophy and engineering to twentieth century physics and its applications that has characterized the work of this eminent American man of science. That he appreciates the tribute The Franklin Institute pays to his achievements in awarding him The Franklin Medal he has shown by making the long journey to receive it from your hands, Mr. President, and by preparing an address for this occasion. I have the honor and take great pleasure in presenting to you Dr. Thomas Corwin Mendenhall.

The President then said:

Doctor Mendenhall: I have the honor, in the name of The Franklin Institute, upon recommendation of its Committee on Science and the Arts, and in recognition of your distinguished services to humanity rendered in the field of science, to present you The Franklin Medal and Diploma, the highest honor in the gift of the Institute.

On receiving the medal, Doctor Mendenhall said:

Mr. President, Members of The Franklin Institute: It is a great honor to receive at your hands this Certificate of Admission to the ranks of the eminent men upon whom The Franklin Medal has been bestowed. I beg to express my high appreciation of this honor and to offer my grateful thanks for the distinction thus conferred.

In previous awards this medal has generally and wisely gone to those who are still vigorously aggressive in the cultivation of that department of Science or Art in which they have won distinction. It has gone to those whose intellectual faculties are still "in commission" and though distinctly given for work already accomplished it has been, in some measure, like gratitude, a pleasing "recognition of favors to come."

In the present instance, however, the Institute has generously departed from this wholesome practice, in awarding it to one whose productive activities ceased a good many years ago. During these years there has been important progress in methods, and important results have been achieved, in those somewhat restricted areas of scientific investigation, my own contributions to which have been thought worthy of recognition by the Institute. He then proceeded to read the following paper:

SOME METROLOGICAL MEMORIES.

BY

THOMAS CORWIN MENDENHALL, Sc.D., LL.D.

THOUGH generally familiar with the more recent advances in physical science, I have had no important part in them. I have chosen, therefore, to indulge in some recollections and reminiscences of work done a quarter and a third and even a half century ago; pioneer days in one of the most extensive fields in which theory and practice have joined hands.

In the progress of Science and Art the most interesting and, indeed, sometimes the most important incidents rarely find their way into the cold record of printed reports or official documents and I am assuming that the future historian will not regret finding some of them, even if trivial in themselves, permanently recorded in the pages of the JOURNAL OF THE FRANKLIN INSTITUTE.

Reminiscence is the peculiar pastime of advancing years. Its enjoyment, however, is often marred by the seemingly unavoidable necessity for the frequent injection of the personality of the speaker. In respect to this I can only ask you to be charitable and to remember that without it reminiscence is impossible. Besides, I have the sanction of Cicero (than whom on this subject there can be no greater authority), who declared that to speak much of one's self is the privilege of old age.

We are going back, then, to a period previous to the apotheosis of science; to a period when those engaged in scientific research, even for a very small portion of their time, were but a handful compared with the thousands of to-day, to whom it is a regular occupation; when the simplest appliances for experimental investigation had to be paid for out of the generally meagre income of the experimenter, or, more frequently, constructed with his own hands.

Within the last quarter of a century science has enriched the world and the world has shown its gratitude by pouring back a fine share of its riches into the lap of science who now sits, hesitating and embarrassed, hardly knowing how to behave under such novel conditions.

Those whose memory stretches over a half century or more, recall with affection the crude apparatus of Faraday, out of which sprang the infant dynamo, and the embryo electro-magnet of Joseph Henry which, by mating with Faraday's infant, became the paternal ancestor of all the giant electro-motors and power plants of the present day. And sometimes they ask themselves if, after all, science is not just now contending with some of the obstacles and embarrassments that usually attend the progress of the *nouveau riche*.

Few of those actually engaged in research in either pure or applied science (for the word research may be legitimately used in relation to certain phases of applied science) have any notion of the difficulties under which the business was carried on thirty or forty years ago. In electricity, for example, the strongest currents available were those generated by Grove's or Bunsen's batteries and when, by combining a number of these, currents of considerable strength were obtained, insulated wire sufficiently heavy to carry them was often not obtainable and the difficulty had to be overcome by the use of long strips of muslin, dipped in hot glue and applied with a large measure of unflagging enthusiasm.

About fifty years ago the induction coil, one of the first important results of Faraday's splendid discovery, came into useful prominence as a source of "high tension" electricity largely through the ingenuity of an American instrument maker named Ritchie, who hit upon the device of winding a number of flat, thin coils and joining them together, thus avoiding the danger of a short circuit due to the proximity of two points differing greatly in electric potential. The importance of this improvement can hardly be overestimated, for besides making possible various practical applications of the coil it greatly facilitated the study of the electric discharge *in vacuo*, with the epoch-making discoveries resulting therefrom.

As an illustration of our ignorance at that time of the potentiality of the electric spark it may be worth while to relate an incident in which one of Ritchie's Coils was used in an experiment that, as far as I know, was, and still remains unique.

I had obtained from the maker a coil of modest dimensions, but capable of giving a very heavy spark about five inches in length. In the city in which I was then living nothing so efficient had been seen and its performance created much interest among physicians and others interested in electricity. The probable physiological effects of the spark were frequently discussed, and as it happened that a criminal was soon to suffer capital punishment it was quietly proposed that permission be obtained to test the matter upon the body of the man immediately after his execution, with the possible result of restoring him to life.

The interest of the sheriff was enlisted and within a very few minutes after the victim had been pronounced dead (by a physician who was entirely ignorant of our plans) the body was lying on a laboratory table, surrounded by a small group of those who had contrived the experiment, together with a few invited guests, including the Judges of the Supreme Court of the State, who were considered useful witnesses in case the unexpected should happen.

The application of the induced current produced a very astonishing exhibition of muscular action, including violent movements of the arms, legs, head and eyes, perhaps less rapid, but as great in amplitude as would have been possible had the subject been actually alive. The magnitude of the reaction fell off rapidly, however, though it had not entirely disappeared at the end of six hours from the beginning.

One of the two or three who collaborated in this experiment was Dr. Theodore G. Wormley, the famous toxicologist, who later and for many years was professor of chemistry in the Medical College of the University of Pennsylvania. It was a somewhat spectacular performance and I think it brought to us both more fame of a certain kind than we desired or had any reason to expect, for it happened that a young man had been sent to "report the hanging" by a newspaper in New York called "The Police News," and in some way he had managed to be a witness of the experiment. A subsequent issue of the journal carried a large and ghastly illustration of the scene, with alleged portraits of the principal participants.

An examination at the conclusion of the experiment revealed the fact that the neck of the criminal had not been broken by the fall, and looking at it from the standpoint of modern theory and practice, it would seem that if our treatment of the case produced any result it was rather in the way of ratifying the verdict of the jury than otherwise.

On the afternoon of July 3, 1876, I completed the installation of an electric arc light on the top of the dome of the State House at Columbus, Ohio, the first flash of which, at the precise moment when the third of July became the fourth, was the signal for an outburst of cannonading, sky-rocketing, drum beating and other forms of patriotic noise which ushered in the Second Century of the American Republic. It is said to have been the first arc light publicly shown in the State and its preparation involved much labor because at that time the only available means of generating an electric current sufficient to produce such a light was a voltaic battery of fifty or more cells which had to be transported through a narrow and winding stairway to a height of about one hundred and fifty feet. A few weeks later, in one of the halls of the Centennial Exhibition at Philadelphia I saw, for the first time, a small machine which was destined to make the repetition of such a performance forever unnecessary. It was one of the several epoch-making exhibits in that wonderful collection and was known as the "Gramme Machine," named for its inventor who, ten years after the original discovery by Pacinotti, of Florence, had rediscovered and applied an improved method of winding the armature of a dynamo, the success of which established the fact that the child of the genius of Faraday and Henry was now big enough to be put to work. The small machine was an object of great interest to students of physical science and to the intelligent public generally. I have a very vivid recollection of being joined, during one of my frequent visits to it, by a party of two or three gentlemen, one of whom impressed me by his splendid physique and "kingly bearing," and who, indeed, turned out to be the Emperor of Brazil, whose great interest in, and knowledge of, matters relating to literature and science was well known.

From that day to this the development of the methods of producing and utilizing electricity has proceeded with a rapidity and on a scale unparalleled in the history of industrialism. The explanation is simple and is contained in a single sentence. *Electricity Was a Science Before it Became an Art.* Compared with it, the utilization of steam as a means of transferring energy has advanced at a snail's pace, because steam was an art before; through the discovery of the laws of thermo-dynamics, it became a science. In the case of electricity, especially, the science became an exact science and the transition to the art was made rapid and easy, through the application of the principles of metrology, the science and art of measurement. Within seven years after the exhibition at Philadelphia the Commissioners of the Cincinnati Exposition were offering large prizes for the best system of electric lighting—both incandescent and arc—with the announcement that the award was to be based upon actual measurement of the efficiency of the machines, with definite comparisons of the "ingo and outcome" ratio, in each of the several competing systems.

In the development of the science of electricity a beautiful system of units for electric measurement had been devised, based on the fundamental units of length, mass, and time of the metric system. It was scientifically perfect to begin with and capable of being applied in practice to any desired degree of precision. To its use, more than to any other single factor, must be attributed the phenomenally rapid development of this branch of applied science during the last two decades of the nineteenth century.

The tests made at Cincinnati are said to have been the first attempt in this country to apply these units and methods of electric measurement on a commercial scale. There were several competitors and not all of them realized that the new method of finding which was best, might bring very different results from the old-fashioned way (still persisting in certain regions of competitive industry), which consists in having the jury "take a look" at the several exhibits, to be followed by a friendly chat with the exhibitors. The Chairman of the Cincinnati Jury has not yet forgotten that it brought him, for the first time, into professional relations with the legal fraternity, because of a suit for damages amounting to fifty thousand dollars brought against him by one of the exhibitors who, by unanimous vote of the jurymen did *not* receive the first prize. However, the voltmeter, ammeter and dynamometer were triumphant, as they always will be; the verdict of the jury was not set aside and no damages were collected.

A year later came the memorable Electrical Exposition of 1884, under the auspices of The Franklin Institute, the first of its kind held in this country. There were many notable exhibits and many interesting comparative efficiency tests were made with a variety of measuring instruments, nearly all of which would be regarded with mingled curiosity and amusement by the present generation of electrical engineers. I recall one, of which we were rather proud at the time, an immense "tangent" galvanometer the coil of which consisted of a single turn, five or six feet in diameter, of a large copper rod capable of taking without shunt the heaviest current the machines could generate.

It is worth remembering that the exposition was one of four nearly contemporaneous events, each significant of the dawn of a new era in the history of pure and applied science. Running nearly parallel to each other were the Electrical Exposition in Philadelphia; a course of lectures under the patronage of the Johns Hopkins University in Baltimore, by Lord Kelvin, who there elaborated his celebrated mechanical theory of light, to which he clung with more or less tenacity to the end of his days; an International Time Conference in Washington out of which came the uniform system of time-meridians by which the world has been so much benefited; and, most important, at least in point of numbers, the annual meeting of the American Association for the Advancement of Science in Philadelphia. The interest and importance of this meeting was greatly enhanced by the presence of the leading men of the British Association, which had adjourned its meeting, held that year in Montreal, in time for its members to reach Philadelphia for the opening of our own first session.

These several events drew together, in Philadelphia or its vicinity, a host of men interested in science. The meeting of the American Association was the largest in its history up to that time and for many years afterwards. The International Time Conference was composed of official delegates from nearly all civilized countries of the world and the remarkable series of lectures by Lord Kelvin had attracted students of advanced physics from all parts of our own country, with a good number from abroad. The managers of The Franklin Institute showed great wisdom in selecting this as the time for holding the first American Electrical Exposition.

Contemporaneous with and intimately related to it was the "Electrical Conference," lasting for a week during which Americans and many eminent English scholars joined in the discussion of important problems, many of which had arisen in the application of theory to practice in the construction of dynamos and other electric appliances. Of those who were the most active in these debates there are to-day few survivors, but I recall with pleasure the modest confidence of a young man who, while still a teacher in the Central High School of Philadelphia, had attacked the problem of the dynamo with great enthusiasm and marked success, and who was destined to become one of the founders of the greatest electrical industry in the world, to the scientific and technical success of which he continues to be, after a third of a century, one of the most important contributors.

I recall one incident in connection with that conference which I venture to relate as an interesting illustration of one of the curious phases of the mental activity, or inactivity of its president who was justly considered the most distinguished American physicist of his day. That Rowland was a "genius" no one will deny and naturally he exhibited some of the weaknesses usually associated with those who have over-specialized. At the age of twenty-four years his first contribution to the literature of science appeared in the JOURNAL OF THE FRANKLIN INSTI-

TUTE and a year later he had completed an original investigation of profound significance which at once gave him a reputation abroad. From that day he continued to cultivate his own chosen field so assiduously and intensively that he seemed to have neither time nor desire to look over the wall in order to learn what was doing or had been done in near-by areas. As president of the conference he opened its proceedings with a long and most interesting address in which he reviewed the history of electrical discovery from the time when Thales observed the attractive power of amber to the modern dynamo and Maxwell's electromagnetic theory of light. At the proper epoch he referred, though at no great length, to the work of Franklin, enumerating briefly the principal facts for a knowledge of which the world is indebted to that great natural philosopher and ending with the remark that, " Truly, our country and this city should honor the memory of this man." The address possessed much literary merit and included an eloquent appeal for the cultivation of " pure science "—regardless of all considerations of its practical value.

But in the opinion of many of his American confreres his address was marred by a grave oversight. The work of only two Americans was referred to, while regarding that of a third, the importance of which was generally thought to rank at least next to that of Franklin, there was absolute silence! The feeling of perplexed regret by which some of us were overwhelmed was greatly intensified by the fact that Lord Kelvin, whose address followed that of Rowland, devoted a large part of his time to a eulogium of Joseph Henry and his contributions to our knowledge of electricity, comparing him, as many others have done, to Faraday. Of the men " whose lives have been patterns to the world," he said, " there is none more remarkable, perhaps, than the man of this country, Joseph Henry." He and Faraday were " patterns of scientific investigators. In some cases they went parallel and made similar scientific discoveries. Henry, indeed, preceded Faraday in the discovery of electro-magnetic induction between unmoved conductors. Henry gave the warmest welcome to all practical applications of his discoveries. He sought to make none himself. I know of no other parallel to Henry's action in this respect except that of Faraday himself."

Very soon after the adjournment of the session of the conference at which these two addresses had been given I ventured to chide Rowland for the extraordinary omission of all reference to Henry, whereupon he turned upon me with that brusque abruptness with which all of his friends were familiar, and exclaimed: "*What did Joseph Henry ever do in electricity!*" It was an exclamation and not a query.

The strong personal regard that I had for Rowland from the day of my first meeting with him to the end of his life and the fact that it was my privilege to pronounce his eulogy in the hall of the institution in which he won immortal fame will acquit me of any intention, in relating this incident, to detract in the slightest degree from the admiration and esteem in which he was held by all who knew him, or to lessen the affection with which his memory is cherished by those who had the good fortune to enjoy a close acquaintance with his unique personality. There was indeed no intentional slight—strange as it may seem it was a case of absolute ignorance. The blade which cuts deep must needs be thin. But the incident should be recorded as an illuminating example of the not uncommon tendency among American men of science to under-estimate, or to be quite ignorant of the work of their own countrymen. Until within the past three or four years a foreign postmark has carried great weight.

In the meantime, although the units of electric measurement had been born perfect, as Minerva sprang from the head of Jove, their practical representations were more or less crude. The commercial use of electricity, especially as an illuminant, was growing rapidly. Contracts were being made of a most extraordinary character, often in terms of incandescent lamps or arc lamps with no specifications whatever of the quantity of light they must furnish; in other cases a candle power was guaranteed which, under the circumstances was utterly impossible, though it looked well in the contract. Under these conditions the demand for a system of practical units, backed by authority and of a high degree of precision became imperative. Fortunately the matter was still in the hands of scientific men and they were anxious to secure international uniformity. To this end conferences of an international character had already been held in Paris and agreement upon definitions of practical units of measure had been approached, gradually though somewhat reluctantly, international jealousies having interfered, especially in the selection of names for these units. The celebration in 1893 of the four hundredth anniversary of the discovery of America furnished an opportunity for a gathering in what might be called "neutral territory," at which it was hoped a definite agreement might be reached. An International Congress of Electricians was organized, the meetings of which were largely attended by Americans and by visitors and delegates from all parts of the world.

A restricted number, about twenty-five in all, constituted the "Chamber of Delegates," the members of which had been designated as the official representatives of their respective governments.

The United States Government was represented by five delegates and it may be worth while to put upon record the method by which a selection was made, under the direction of Elisha Gray, of Chicago, who represented, in matters relating to electricity, the Commissioners of the World's Fair. A list was made of the names of all Americans who were then known to be actively and intelligently interested in electricity, including professors in universities, colleges and technical schools, persons connected with electrical industries and others, in all about one hundred and fifty, as I remember. These were requested to cast ballots for their choice of five official delegates and the five persons who received the largest number of votes were recommended to the Secretary of State by whom the appointments were formally made and who had, I believe, suggested this method of selection or at least had approved of it before it was put in operation. The Chamber of Delegates was successful in its work and, though not without much discussion, its members were practically unanimous in the adoption of definitions for the principal practical units of electric measurement. A few years ago I sent to The Franklin Institute an account of how the chamber was brought to an agreement upon the definitions of the three fundamental units, the ohm, the ampère and the volt, together with the original first draft of these definitions, signed by the members of the committee to which this matter had been referred. The Institute has published this account with a reproduction of the original draft and I need make no further reference to it here.

After the work of the International Congress of 1893, the next important step was to secure the legalization of the units there defined by enactment of law or otherwise when possible. In the matter of weights and measures as regards both legislation and practice we are, in this country, still in a condition of chaos, and it is a great tribute to our business capacity that we have managed to get on under such a handicap for nearly a hundred and fifty years. The Constitution puts upon Congress the responsibility of "fixing standards," but in spite of the strong and frequently repeated urging of our first three presidents, Washington, Jefferson, and Adams, Congress has never had the courage to discharge its duty in this respect. As far as the business of the government itself is concerned (except in the matter of coinage of money and up to the time of the legislative action of which I shall shortly speak) the Secretary of the Treasury was the final arbiter in all matters relating to standards, a function now belonging to the Secretary of Commerce, the Bureau of Weights and Measures having been transferred to that Department upon its organization by Congress.

During the period under consideration this Bureau was, as it has been for nearly a hundred years, a Division of the United States Coast and Geodetic Survey and as ex-officio Superintendent of Weights and Measures it was my duty to try to secure formal adoption of the new units; first, by securing the approval of the Secretary of the Treasury, in virtue of which they would become the legal measures for all government transactions concerning electricity; and second, through the passage of a general law which would impose them upon the country as a whole. That the latter should be accomplished as soon as possible was evident from the following considerations. In matters relating to units of measure in ordinary use, pounds, yards, gallons, bushels, etc., we were cursed and still are by the legalization of many different standards in different parts of the country. What Congress has failed to do, individual states have been compelled to do, with the natural result of a lack of uniformity as we pass from one state to another. We are now dealing with a new commodity that could not be measured in pounds or gallons, or yards, and in many places purely arbitrary and unscientific units had already come into use and there was constant danger that some state legislature might undertake to distinguish itself by legalizing them. When we reflect that in recent years there has been an attempt by at least one state legislative body to fix by law the ratio of the circumference of a circle to its diameter, the danger does not seem so remote. In securing the approval of the Secretary of the Treasury to a bulletin from the Office of Weights and Measures announcing the adoption of the new units by the government itself I anticipated little difficulty. My time of trial in that respect had been about a year earlier when, with his aid I had accomplished, on paper, in about ten minutes, what many of us had been struggling for more than a quarter of a century to bring about, in practice, namely, putting the country in the matter of weights and measures upon a metric basis and discarding the yard and pound as fundamental standards. But the paper victory was, in fact, of great value. Even as a matter of strategy it was a position worth taking, for it was an important turn in a revolution that will never go backwards. Previous to the fifth of April, 1893, our real standards of length and mass had been the English yard and pound of which we had imperfect copies. On that day I sat for a short time with the Secretary of the Treasury, having in my hand a typewritten copy of what was to be Bulletin No. 26, of the Office of Weights and Measures, in which I had embodied a brief statement of existing metrological conditions along with the announcement that in the future the standard of length in the United States Government would be the international meter and the standard of mass would be the international kilogramme, very beautiful and perfect copies of both of which we had received from the International Bureau of Weights and Measures at Paris; that hereafter a yard would be defined as a certain fraction of a meter and a pound as a certain fraction of a kilogramme. I had approached the interview with no little anxiety, the forecasting of the attitude of a cabinet minister under any given conditions having never yet reached the dignity of an exact science. However, the secretary, John G. Carlisle, of Kentucky, showed an intelligent interest in my discourse and without making any objections affixed his signature to the paper. After the lapse of a quarter of a century during which there has been no going back on this action, I may be allowed to confess that I have never had greater pleasure in seeing a government official sign his name than on that occasion.

The principal obstacle to the passage of an Act of Congress legalizing the electric standards for the whole country was the well-known inertia of legislation which is sometimes so great that measures unanimously approved die because of sheer inability to get themselves out of the committee room. In the preparation of the Electric Units Bill I had the highly valued assistance of the Chairman of the House Committee on Weights, Measures and Coinage, Mr. William A. Stone, of Pennsylvania, who was most actively and intelligently interested in all matters relating to weights and measures. Under his wise and experienced guidance the measure passed both Houses of Congress, and on July 12, 1894, became a law on receiving the signature of the President. The pen with which this memorable act was completed is now in the possession of The Frnaklin Institute along with the original draft of the definitions of the fundamental units already mentioned.

It is perhaps worth while to remark that in accomplishing these results, the importance of which will continue to increase as the years pass, we were greatly aided by the fact that little significance was attached to the measure by the general public at that time. Ohms, ampères and volts had a far-away sound to most members of the fifty-third Congress who did not suspect that they were soon to be used in measuring an annual output valued at hundreds of millions of dollars.

In somewhat remote connection with the Electrical Congress of 1893 there occurred an incident so purely personal in its character that I should never think of relating it in public were it not that the deplorable events of the past three or four years have given it a new significance, such as, in my opinion will justify its preservation in print.

The Honorary Chairman of the Congress, by unanimous choice of the committee of arrangements, was Baron von Helmholtz, of Berlin, almost equally famous as a mathematician, physicist and physiologist, and without doubt the most distinguished natural philosopher Germany has produced. He was accompanied on his visit to this country by his wife, and after the close of the Congress the two spent some days in Washington affording some of us an opportunity of knowing them more intimately. On one occasion, while in conversation with Baroness von Helmholtz, she said to me: " Do you know how my husband happened to come to this country?" I replied that I knew only that we had invited him and were very glad that he was able to accept, for at first he was disposed to decline on account of his advanced years. "Well," said she, " it happened in this way.

The Kaiser sent for him. 'Von Helmholtz,' he said, 'we are sending to this World's Fair in America the finest products of our factories, our mills, our fields and our mines; some of our choicest works of art will be there, but above all of these Germany is most proud of the men she produces. You are the best we have and you must go to represent us.'"

The Baroness told me this with evident and justifiable pride; and then, after a short pause which seemed reflective in its nature she turned to me and with upraised finger and flashing eye, added: "But do you know that when my husband walks the streets of Berlin he is pressed off the sidewalk by any petty lieutenant in the army whom he may happen to meet?" I confess to finding a ray of hope in this incident.

Metrology is fortunate in that it is both a science and an art, its two phases being mutually inspiring. So clearly is it related to the progress of civilization that the degree of precision which a nation demands in its weighing and measuring is an almost infallible index of the enlightenment of its people. Measured by this standard our own country ranks among the first. The establishment a few years ago of a National Bureau of Standards was the one thing needed to give it, in this respect, a place among those nations which, at least until recently, we were accustomed to call the "most enlightened." During the few years of its existence it has accomplished extraordinary results in the dissemination of both the principles and practice of accurate mensuration among the people generally.

In Michelson's Wave-length Standard we have found a natural unit of length, corresponding in the degree of accuracy with which it may be determined to our natural unit of time and perhaps more permanent than that, a contribution to the science of metrology of great value. To the art of metrology we have also contributed much.

If time permitted I should like to speak at length of some of the wonderful accomplishments of this art-science, but I must content myself with a brief reference to some of the results that are easily reached in the case of the fundamental magnitudes, time, length and mass.

For time, Nature has given us a unit of measure, the period of the revolution of the earth on its axis, which, as far as we know, has not varied during the historic period, though it is well known that forces are at work which must have affected it and which will continue to affect it, until sometime in the remote future the change can be detected. With such an excellent and comparatively stable unit our derived measures and measuring devices are very satisfactory. Any given interval of time may be determined with almost any desirable degree of accuracy. Astronomers tell us the length of the mean solar year within a tenth of a second, which means that the result is correct within one part in three hundred millions. On the other hand, a small interval of time, even smaller than a second, may itself be determined within one part in a million or perhaps more accurately.

The length of a bar approximately one meter long can be ascertained in terms of our unit of length with a probable error of one part in thirty millions. Of all measurements depending upon arbitrarily chosen, non-celestial units the process of weighing is by far the most accurate. A mass of matter can be compared with our standard with a degree of precision measured by a probable error of one part in three hundred millions. The balance almost rivals the multiplication table in accuracy.

So highly developed is the art of metrology that in the application of laboratory methods to practical measurements, an almost equally high standard may be maintained. The United States Coast and Geodetic Survey has for many years required in all of its more important geodetic operations a degree of precision ranking very well within the results given above, especially when the great difficulty of out-door work is considered. Base lines six or eight miles in length are measured with a probable error of one part in three millions; that is, for the whole distance the error might be as much as one-eighth of an inch. The probable error of a field determination of the value of gravity is about one part in a million. The latitude of a station is determined with a probable error of not more than one-tenth of a second, which means that the position of a point in latitude is known to within a distance of about ten feet. In longitude the same order of accuracy is reached. The probable error of a single observed direction, as in the system of primary triangulation, is sometimes less than a quarter of a second, a quantity that may be visualized by the statement that one of the great guns with which, unhappily, we are becoming familiar, if pointed with the same degree of accuracy and assuming no other cause for deviation, should deliver its shot at a distance of seventy-five miles within a circle of about five inches in radius.

Metrology, itself both a science and an art, is the mother of science and of art; certainly of all the exact sciences and of nearly all of the arts. Without it there could be no astronomy, no physics, no chemistry, no engineering, no architecture. There could be no trade, no commerce; take it away and the whole fabric of civilization would disappear. It is a great pleasure and privilege to sound its praises in the hall of an institution that has contributed so largely to its development.

Electric Arc-welding in Railroad Shops. ANON. (*Railway Age,* vol. 64, No. 14, p. 898, April 5, 1918.)—Welding is now demanding more attention than any other branch of the electrical field. It is used effectively on steel and cast-iron and experiments on other metals, such as bell metal, have proved that the use of arc-welding is not limited to iron and steel. Its use on railroads is being steadily extended.

In the locomotive repair shop arc-welding is used for making almost every kind of repair. Broken locomotive frames are repaired quickly and with little cost; cracked and broken cylinders are repaired without removing the cylinders from the locomotives; broken fireboxes are repaired; flue sheets are welded into boilers without the use of rivets, and it has become quite common practice to weld the flues to the sheet at the firebox end of the boilers. A cross-head guide was worn down until practically useless, and then built up by the metal electrode process. After it has been machined it will be put into service again. This practice is not limited to flat surfaces only, but applies equally well to cylindrical forms which are in need of bushing. Extensive tests have shown that it is possible to make a weld stronger than the original metal. This statement is true for cast-iron as well as for steel.

The savings made possible by the use of electric arc-welding are apparent to anyone who has seen it in use. The superintendent of a large Eastern shop recently said that by the use of improved shop methods and electric arc-welding they had been able to maintain total operating costs constant in spite of the tremendous increases in cost of labor and material.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

EFFECT OF THE SIZE OF GROG IN FIRE-CLAY BODIES.[1]

By F. A. Kirkpatrick, Assistant Physicist.

In those industries which use crushed and ground raw materials in forming bodies by means of a cementing action of some sort, the size of the particles plays a most important rôle. This may be in many instances the main factor controlling the desired properties in the body. This is nowhere more true than in the ceramic industries, where in compounding bodies the manufacturer is compelled to use materials from the size of pebbles down to the dispersoid and emulsoid (colloidal) states. All present evidence tends to show that in disperse systems the size of particles which we cannot now measure has as much effect upon the properties of certain materials as have the larger sizes which we are able to measure. In no other way is it possible to account for the great differences in cementing power exhibited by fine-grained bond clays and other fine-grained materials. In practice the cementing action takes place at temperatures from zero to that of the electric arc, depending upon the nature of the process, and is due to many different chemical reactions. In the present work the bonding power of mixtures composed of raw clay and calcined clay is determined after these bodies have been heated to 110° C. and to 1250° and 1300° C.

The control of the strength of raw fire-clay bodies is a difficult matter into which enter a number of factors. Those which are directly connected with the size of grog are size of the body, cracks formed in drying, density or porosity, and size of grain of the clay.

If the grog is too large for the size of the body used, the conditions of bond are different than for smaller grog. Small cracks may or may not form in drying. Hence, it is possible that the curve of Fig. 4 would be much different for test pieces of larger dimensions. The general rule in ceramic bodies is that strength increases with decrease of porosity. This factor may be overruled by others, as the results in Fig. 4 show. In series 4, however, the rule holds. As shown in connection with series 5 and 7 the size of grain of the bond clay also affects the strength of the body. In regard to the grog, aside from other considerations, the following condition is necessary for highest strength: The mixture of sizes must be such that the smaller particles fill the voids between the larger, giving maximum density. The proper proportions may be predicted qualitatively from the ratio of sizes, but can be determined accurately only by experiment.

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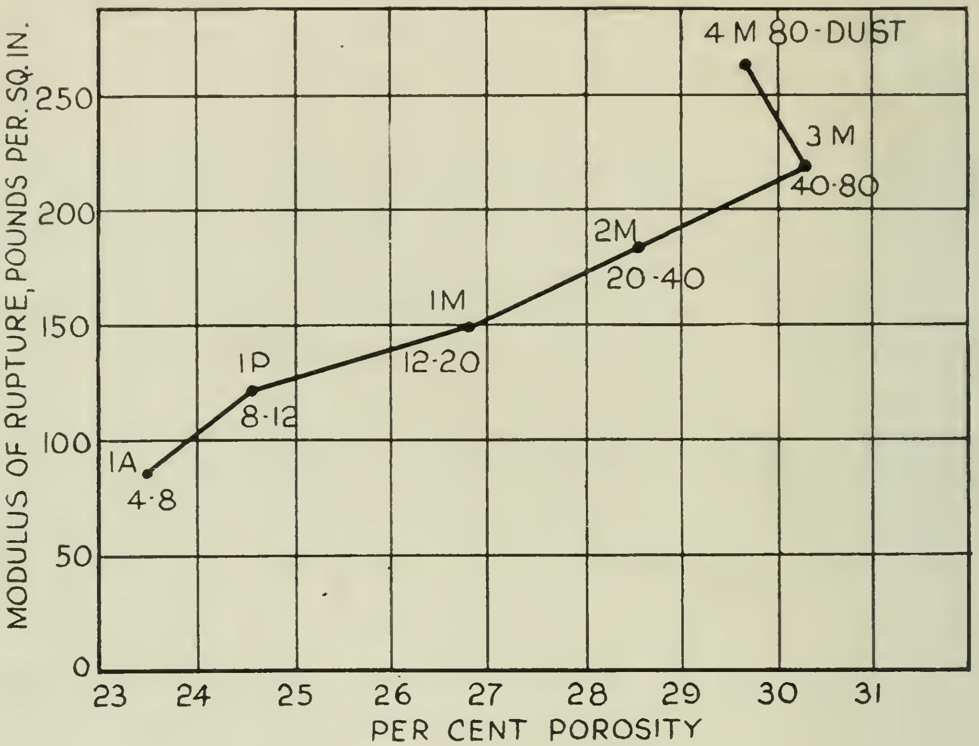
* Communicated by the Director.

[1] Technologic Papers of the Bureau of Standards, No. 104.

Fig. 4.



The strongest raw bodies were those in series 4 and 7. In series 4 these had the following limits of grog composition: 25 to 66⅔ per cent., 20 to 40 grog; 0 to 25 per cent., 40 to 80 grog, and 33⅓ to 66⅔ per cent., 80 to dust grog. In series 7 the strongest bodies were those containing the greatest percentage of 80 to dust grog.

The control of strength in the burned state proved to be not at all difficult. For all bodies used the modulus of rupture was found to increase with increase of surface factor. The relation was represented by means of straight lines except that the lower portions of some of the curves representing large-sized grog were of parabolic form. The rate of increase of strength increased with the temperature of burning, due to the more rapid rate of solution of the finer particles at the higher temperatures. The porosity at cone 12 varied much the same as in the raw bodies and had little relation to strength. The strongest bodies were those in series 4 (20 to dust grog). No relation was found between strength in the raw state and in the burned state.

In the quenching tests from 600° C. and 1000° C. mixtures of the larger sizes of grog gave the more resistant bodies.

Development of the Pneumatic Tire. Anon. (*Scientific American*, vol. 118, No. 1, p. 10, January 5, 1918.)—The pneumatic tire has been generally regarded as a device of comparatively recent origin, but as early as 1846 it was successfully tried in London. In that year the frequenters of one of the parks of the British metropolis were treated to a genuine surprise by the appearance of a brougham equipped with extraordinary tires upon which the vehicle seemed to float along the road without jar or noise. They consisted essentially of an inner and outer band of leather, about a foot wide, enclosing between them the pneumatic tube by being brought together around the tube and permanently riveted along one edge and laced along the other edge. These pioneer pneumatic tires were known as " patent aerial wheels " and were the invention of Robert William Thomson, who patented the idea in 1846. Such large tires naturally gave the vehicle an unusual and unattractive appearance, and that may explain why, in spite of excellent performance in service and in tests, in that day when the question of appearance rather than utility received paramount consideration, the proved merits of the pneumatic tire were ignored and remained unrecognized until the introduction of velocipedes and bicycles in the 70's, but mostly in the early 80's, created new interest in the tire question. In substance the patents of that period related mainly to the general design and means of attachment of solid tires, and only one patent applied for in 1884 varies from the solid-tire idea in calling for a hollow-centre tire, or porous or spongy centre, in order to obtain greater resiliency.

The real beginning of the present-day pneumatic tire starts from the year 1888 with the single-tube tire held to the rim by wrappings of tape, invented by John Boyd Dunlop, a veterinary surgeon of

Belfast, Ireland, from which eventually grew a tremendous tire manufacturing business. Rapid progress was made, and in 1895 the Dunlop interests took the form of a $25,000,000 corporation, which for a while enjoyed a practical monopoly in Great Britain and made extensive sales elsewhere. Casting about for a better means of attaching their products, the Dunlop interests came across the patent of Charles Kingston Welsh, who had been granted an English patent in 1890. In addition to an air tube, Welsh's patent provided a cover of rubber and canvas having thickened edges, through each of which ran a reinforcing wire. The last-mentioned member formed a complete circle, and when applied to the rim it engaged the grooves especially shaped for the purpose. An American patent covering the identical idea was granted to A. T. Brown and G. F. Stillman, of Buffalo, N. Y., in 1892. This was acquired by the Dunlop interests for the sum of $100,000 and served as the foundation for the extensive Dunlop business in America at a later period.

In 1890 the Dunlop interests acquired the patent rights to the invention of William Easkine Bartlett, covering the clincher principle of tire attachment. Instead of wires for holding the tire in place, the cover was made with beaded edges which engaged the incurving flange of the rim. The tire was first inserted in the rim and then inflated so that the beaded edges became tightly wedged in place. It is said that $100,000,000 was paid for the patent rights, the vendors besides retaining certain shop rights. A similar clincher tire was developed and patented in the United States by Thomas B. Jeffrey in 1891 and 1892. For bicycle use the single-tube tire became the most popular. However, with the advent of the automobile the clincher tire took first place in practically every country where motor vehicles appeared.

Automobile development has been consistently accompanied by tire development. Of late, tire fabric has been somewhat altered, for it is found that heavy cords give better service than the woven fabrics usually employed. It was a long step in the manufacture of commercial tires from the 1½-inch bicycle tire to the 4½-inch automobile tire in a year or two. The limit in size seemed to be governed by the resistance of the close-woven fabric to the deformations incident to the manufacture of the larger sizes. Progress in tire design during the past two years has shown that this limit no longer holds if laminated cords without cross weave are used instead of woven fabric. These cords take the strain without undue fatigue, and now we see our way clear to make 12-inch tires just as readily as 4½-inch tires. At this time pneumatic tires are being employed on very heavy motor trucks, which, with their 12-inch tires, are maintaining regular transportation service between distant cities and in this manner relieving the war-time congestion of our railroads.

No better proof of the magnitude of the pneumatic tire industry can be offered than the fact that in 1917 some 18,000,000 tires were sold, which, at an average cost of $25, totalled $450,000,000.

NOTES FROM THE NELA RESEARCH LABORATORY.*

ULTRAVIOLET TRANSMISSION OF CLEAR AND COBALT-BLUE GLASSES.

By M. Luckiesh.

Several years ago while developing certain blue glasses the writer noticed that cobalt glass appeared to be more transparent than clear glass to ultraviolet rays in the neighborhood of 300$\mu\mu$. No systematic observations were made at that time, but in spectrophotographic work carried out subsequently this observation was verified on various occasions. Recently conclusive evidence was obtained by means of clear and blue glasses (soda-lead) of (1) equal thicknesses and (2) of the same content except that the blue glass contained in addition a very small percentage of cobalt. Clear and blue specimens of the same thicknesses were compared in pairs by photographing the spectrum of the quartz mercury arc through each. Various thicknesses were studied, but for each comparison pair, the thickness of the two glasses was the same, and the photographic exposures were identical. These experiments established the fact that the glass containing the slight amount of cobalt was more transparent to the mercury lines near 300$\mu\mu$. However, owing to the gaps in the mercury spectrum, it was desirable to use a source of radiation which was richer in energy in the spectral region of interest. Clear and blue glasses of the same thicknesses were fastened side by side by means of a narrow strip of gummed paper and were so placed across the slit of the spectrograph that the blue glass covered half the length of the slit and the clear glass the other half. Through such pairs, spectra of skylight, of the bare iron arc, and of the quartz mercury arc were obtained. This arrangement eliminated any photographic errors and care was taken to have the slit illuminated uniformly throughout its length. Various densities of the blue glass were studied in testing pairs of different thicknesses. An idea of the density of the blue glass may be obtained from the observation that at the lightest densities it transmitted about one-third of the light from a tungsten filament (Mazda C) lamp. None of the specimens would be considered dense. The difference in the spectral transmissions is, of course, more conspicuous on the original negatives than on prints or half-tones because such photographs suffer materially in printing and half-tone processes. In the accompanying illustration the spectrum at the top is that of a bare quartz mercury arc obtained

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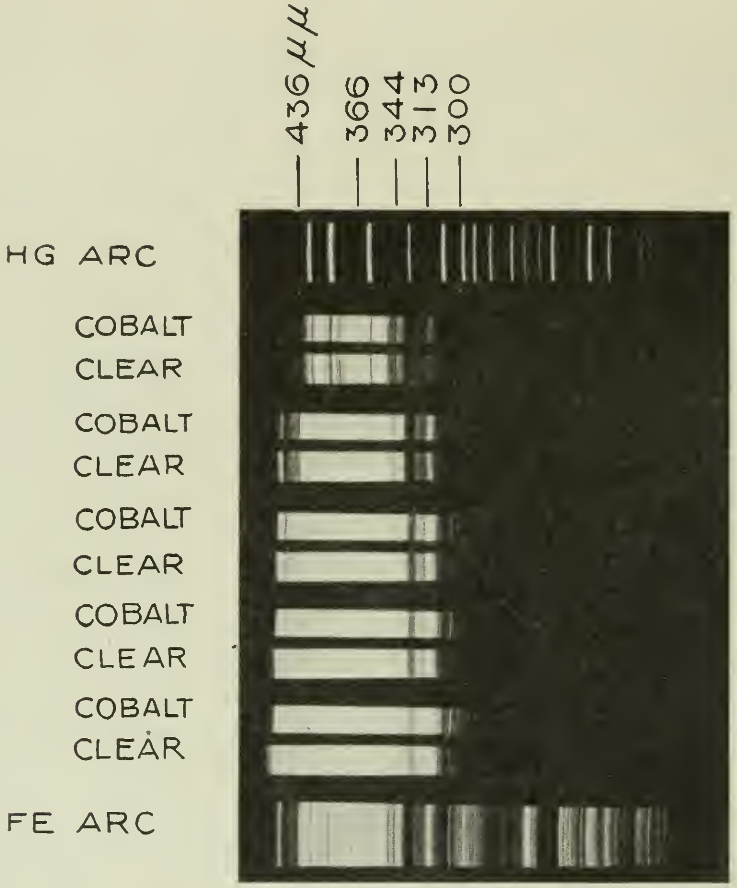
* Communicated by the Director.



with a quartz spectrograph. In the five pairs following, the upper spectrum in each case is that of the iron arc through cobalt-blue glass and the lower is the spectrum of the same illuminant through clear glass of the same content except for the addition of cobalt in the blue glass. Each pair represents results from the two kinds of glasses of equal thickness under identical photographic and illumination conditions. In fact, the two spectra of a pair were made simultaneously. The spectrum at the bottom is that of the bare iron arc.

Since this observation was first made it has appeared to the writer that certain blue glasses which have been developed chiefly for scientific purposes owed a portion of their satisfactoriness to this augmented transparency in the region of 300$\mu\mu$. From a purely theoretical standpoint this result is not particularly startling; nevertheless, from a practical viewpoint, it has been somewhat surprising. No quantitative measurements of the difference have been made, but it is obvious that the difference is appreciable. For this reason the addition of a slight amount of cobalt may be of practical advantage in some cases.

CLEVELAND, OHIO, June, 1918.

Hydraulic Rams for City Water Supply. T. H. CARVER. (*Engineering News-Record,* vol. 80, No. 21, p. 1000, May 23, 1918).—The Maple Leaf pumping station of the City of Seattle represents a new departure in the common practice for the construction of water-power pumping stations. This plant should be of interest to engineers, since it is believed that it develops perhaps the highest known combined power and pumping efficiency of any existing plant of like size or larger, and in addition shows unusual economy in installation and operating costs. It consists of two 12-inch Hill hydraulic rams operating under a 50-foot power head and against a pumping lift of 140 feet from a point above the rams to the full tank level. Performance tests showed a range of capacity of water pumped from 720,000 to 1,300,000 gallons per day with corresponding efficiencies of from 90.8 per cent. to about 85 per cent. The normal daily operating capacity is something over 1,000,000 gallons of water pumped.

Eventually the plant capacity will take care of some 28,000 population and furnish ample fire protection for the 790 acres involved. The rams are simple in operation. They are started with an auxiliary starting valve, and adjustment for capacity is made by turning an adjusting screw up or down. All mechanical movement is limited to simple valve shifts of small motion, and as all moving parts are inside the machines, in water, no oil is used or required. The rams operate continuously in the locked gate house and inspection is made only once or twice a week by the regular water department employee. Maintenance and renewals, limited largely to new valve seats, are estimated to cost not to exceed $10 per year per ram. As wear is exceedingly light, the rams maintain their full efficiency for long periods.

Ball Bearings for Electric Motors. A. H. MACCAFFRAY. (*American Machinist*, vol. 48, No. 15, p. 613, April 11, 1918.)—Compactness is required under conditions usually found in general industrial applications for both alternating-current and direct-current motors. To obtain this, motor manufacturers develop, or try to develop, the greatest possible horsepower from given frame sizes. The reduced size per horsepower capacity gives greater output for acquired motor space.

Babbitt bearings are usually designed with an over-all length of two and one-half or three times the diameter of the shaft which they are called upon to support. Contrasted with this, the length of the ball bearing proper on the shaft usually is not over one-third of the shaft diameter. Through ball bearings the over-all length of motors can be reduced from 10 to 30 per cent. To be sure, on motors in which the shaft is subject only to torque, bearing friction is a small percentage of the motor loss. This condition obtains for the most part in direct-coupled units, such as pumps, motor-generator sets, etc. These bearings carry little, if anything, above the weight of the rotor, and the pressure between the shaft and the bearing is slight and friction is at a minimum. Wherever such motors are running at high speeds even slightly unbalanced forces will produce considerable bearing loads that tend to increase friction and wear. Where the shaft is subjected to bending strains, bearing friction becomes an important consideration. This is the case of belt- or gear-driven motors. The bearings are subject to severe binding, pounding, or shock, especially at the drive end. Ball bearings in these instances show a very decided saving over plain bearings, especially if the self-aligning type, which compensates for shaft deflection or misalignment, is used. Power saving in ball bearings is entirely due to the fact that their friction is practically constant over a wide range of loads and because rolling is substituted for the rubbing action of plain bearings. As ball bearings consume no more energy at start than they do at speed, acceleration is rapid and the starting torque improved several hundred per cent. Belt slippage is eliminated and it becomes possible to use smaller belts and pulleys.

To illustrate how a ball-bearing motor will run more satisfactorily under conditions of neglect than a plain-bearing motor, observe how two motors operating side by side, one on ball bearings, the other on plain bearings, will act. The plain-bearing motor, as soon as the oil has become exhausted, will heat up and the bearings will run to destruction, with the likehood of the armature being stripped when bearing wear is sufficient to let the rotor rub on the pole pieces. On the other hand, the ball-bearing motor, because of the lubricant being held in the sealed chambers, and its lubricating properties not being exhausted as quickly as in plain bearings, will run for an indefinite period without showing any signs of heating or bearing wear. A motor of this kind requires oiling only three or four times a year to insure perfect bearing operation.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE EFFECT OF THE IRON CONTENT OF AMMONIUM PERSULPHATE ON ITS PHOTOGRAPHIC REDUCING POWER.[1]

By S. E. Sheppard, D.Sc.

It is well known that different commercial preparations of ammonium persulphate show wide variations in their behavior in attacking the density of photographic negatives. The typical peculiarity of persulphate, namely, its selective action on the higher densities, has received many explanations. In this direction the most important contributions to the chemical mechanism of persulphate reduction are the following:

H. Marshall (*Trans. Edin. Phot. Soc.*, 1900, 23, 168) showed that the action of persulphate on metallic silver is what is termed auto-catalytic, *i.e.*, it is accelerated by the reaction-product, the dissolved silver sulphate. A chemical explanation of this is the formation of an intermediate *silver persulphate*, which is a stronger oxidizer than the ammonium or potassium persulphate; the action in question may be considered to take place in stages represented by the following chemical equations:

1. $2\ Ag + (NH_4)_2S_2O_8 = Ag_2SO_4 + (NH_4)_2SO_4$ Very slow

This reaction, the formation of silver ions by the direct attack of persulphate on metallic silver, is very slow.

2. $Ag_2SO_4 + (NH_4)_2S_2O_8 = Ag_2S_2O_8 + (NH_4)SO_4$ Very rapid

This reaction, a purely ionic interchange, is very rapid.

3. $2\ Ag + Ag_2S_2O_8 = 2\ Ag_2SO_4$ Rapid

Finally, the attack of silver persulphate upon metallic silver, is also a rapid reaction.

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* Communicated by the Director.

[1] Communication No. 60 from the Research Laboratory of the Eastman Kodak Company.

In the absence of silver ions (or other catalyst) the reaction is slow at first, then becomes rapidly accelerated.

By adding silver ions, *e.g.*, silver nitrate or, better, silver sulphate, to a sluggish persulphate solution, the initial retardation is overcome.

It was suggested that this auto-catalytic action of the dissolved silver afforded an explanation of the superproportional action. This, however, is not the case. Unless other factors intervene, the rate of reaction would still be proportional to the density, so that the undoubted acceleration by dissolved silver is not a complete explanation.

Different observers had noted that the water used in making up a persulphate solution affected the action. This was taken up by E. Stenger and H. Heller (*Zeit. Wissent. Phot.*, 9, 73, 1910). They found that, depending upon the amount of chlorides in tap-water, the type of reduction changes from the superproportional to the subtractive. They attribute this chloride poisoning to the formation of relatively insoluble silver chloride, which lowers the concentration of the catalytic silver ions and protects the silver grain from further attack.

It can, however, be shown that even with distilled water free from chlorides the anomaly persists. Schuller (*Phot. Rundsch.*, 1912, p. 236) brought forward more definitely a suggestion often tentatively advanced, namely, differential diffusion. Schuller adopts the silver persulphate or catalytic theory, but considers that superproportional action on the higher densities is much less determined by poisoning in the lower densities than by a restriction on diffusion in the higher densities.

As against these explanations, Lüppo-Cramer (*Colloid Chem. und Photographie*) advanced a colloid chemical theory. He considers that the composition of the developed and fixed negative image is not pure metallic silver, but remains an adsorption compound of silver and photohalide. The amount of photohalide and, *a fortiori*, of normal silver halide, is very small, but it is supposed to be greater in proportion as the exposure is less. There is then more photohalide in the lower densities than the higher. This he suggests is due to a more energetic attack of the developer on the grains of the higher, more exposed densities.

Lüppo-Cramer regards this as an explanation of the peculiarities of photographic reducers. Reducers with a silver halide solvent present in solution with the oxidizing agents—as in Farmer's reducer—will attack the lower densities more strongly than the upper, and we get subtractive action. On the other hand, in reducers like persulphate, or in chromic acid poisoned with soluble chloride, the lower densities having more halide are better protected from attack.

It is to be noted that the facts and explanations brought forward still fail to account for certain minor characteristics of persulphate reducers. One of these is the already mentioned variation, particularly of initial activity, between different preparations having the same persulphate content. Another is the action of acid and alkali on this initial activity.

Lüppo-Cramer, in support of his photohalide theory, instanced the equalizing action of sulphocyanide (a silver halide solvent) upon ammonium persulphate. This combination was first recommended by Bayley and Puddy (*Phot. News,* 1900, p. 174) as giving a proportionate action.

In the course of some experience intended to test Lüppo-Cramer's views on the negative image, Bayley and Puddy's combination was tried. It cannot be said that it is very satisfactory either chemically or photographically. In the first place, like other complex cyanides, sulphocyanide is attacked by persulphate with the liberation of hydrocyanic acid. In the second, measurements with sensitometer strips show that there is no certainty of proportionate action.

In trying the combination with different persulphate preparations it was observed that they all reacted, more or less vigorously, for *iron.* Further, it was noted that the preparation showing the least initial activity, or the greatest initial sluggishness, gave the weakest reaction for iron, while the most vigorous preparation, one, in fact, very difficult to control, gave the strongest reaction.

The preparations were therefore analyzed for iron, with the results given later.

On adding ferric sulphate to the solution weakest in iron till it was approximately equal in this respect to the strongest, the initial activities were made practically equal. Quantities of iron in excess of this relatively small amount gave reducers of uncontrollable character, the action becoming very irregular and localized.

The small variable amount of iron salt present as an impurity in ammonium persulphate is thus the cause of its variability, and iron, however introduced, is a powerful catalyzer of the action of persulphate on metallic silver. The chemical reactions involved show that we have here a case where a side-reaction supplies more rapidly the auto-catalyst for the main reaction, while the main reagent re-energizes the side reagent or catalyst. Iron, as a ferric salt, *e.g.*, *ferric sulphate*, rapidly attacks metallic silver, forming silver sulphate and ferrous sulphate:

4. $Fe_2(SO_4)_3 + 2\ Ag = Ag_2SO_4 + 2\ FeSO_4$

and the *ferrous sulphate* is rapidly reoxidized to *ferric* by persulphate.

5. $2\ FeSO_4 + (NH_4)_2S_2O_8 + Fe_2(SO_4)_3 + (NH_4)_2SO_4$

so that the concentration of ferric iron tends to be kept up to the initial level. Further, the silver salt (or silver ions) supplied by reaction (4) give the necessary acceleration to the persulphate reaction proper, these reactions being those already noted in equations 1, 2 and 3.

The function of the iron then is somewhat like that of a pilot flame. By immediately furnishing silver ions, through reaction (4), it abbreviates the initial retardation and gets the rapid following reactions in full swing without delay. At the same time, the catalytic action of iron explains in part the effect of acidity and alkalinity on the persulphate reducer. So long as an acid reaction obtains, the iron will be in the active ionized condition. If the reaction becomes alkaline, the iron will be progressively removed by hydrolysis, being converted to ferric hydroxide, which, moreover, is strongly absorbed by gelatine, with a tanning effect and probable reduction in diffusion velocity.

It is necessary to note at this point that this iron catalysis does not stand in any contradiction to the other aspects of persulphate reduction. In particular, experiments with iron catalyzed persulphate strongly support the theory that it is a superposition of diffusion conditions upon auto-catalysis which leads to the characteristic persulphate effect. This superposition of diffusion or coupling of diffusion with a chemical reaction in the photographic layer has been frequently noticed, and we can generalize the present result as follows:

1. If in a photographic process the reaction products affect

(accelerate or retard) the primary action, then the speed of this will depend upon their rate of removal and momentary concentration.

2. These products, if soluble, will tend to diffuse away most rapidly in the direction of regions of lower concentration.

3. From the known structure and distribution of the negative image, diffusion, and hence exhaustion, of reaction products will occur more easily in the lower densities than in the higher. Conversely, there will tend to be a superproportional accumulation of the reaction product in the more strongly exposed regions, the lower layers next to the support eventually acting as reservoirs.

Amounts of Iron.—The percentage quantity of iron involved is not of a very large order, as will be seen by the following data:

Sample	Make	Persulphate	Iron per gram Persulphate	Remarks
No. 1....	Commercial	98.3 per cent.	.0006 gram	Could just be used in in 5 per cent. solution. Quite active at once.
No. 2....	Commercial same firm different stock.	97.8 per cent.	.00162 gram	Could not be used in stronger than 2 per cent solution. Very active at once.
No. 3....	Laboratory product.	98.2 per cent.	.000088 gram	Very inactive: in 5 per cent. solution hardly any action in 15 mins. Iron, alum, or silver nitrate brought it up to No. 2.

In a later communication data on the relation of the iron concentration to the action measured sensitometrically will be given. Meanwhile it may be noted that in a 5 per cent. solution persulphate the amount of iron required to perceptibly affect the initial activity in dissolving silver is of the order of 1 part in 1,000,000.

The tolerance or upper limit of iron permissible appears to be of the order of that found in preparation (2), 1 to 2 parts per 1000 of solid persulphate.

My thanks are due to Mr. W. H. Davis for assistance in the experimental work.

Photochemical Activity of Ultra-violet Light. ANON. (*Metallurgical and Chemical Engineering*, vol. 18, No. 1, p. 43, January 1, 1918.)—The photochemical activity of invisible light-waves existing beyond the visible violet of the spectrum has long been a recognized fact, and considerable research has been made to determine the nature and extent of the reactions produced. The shortest wave-length of light perceptible to the eye is about 0.3969μ, in the violet end of the spectrum. Rays of shorter wave-length vary in their activity and effect. Berthelot divided them into four groups: (1) Wave-lengths 0.4 to 0.3μ, comprising the ultra-violet rays that reach the earth's surface in sunlight. These rays are similar to the violet rays of the visible spectrum. (2) Wave-lengths 0.3 to 0.2μ, medium rays of strong photochemical effect, producing marked chemical and physical changes. (3) Wave-lengths 0.2 to 0.15μ, useful in synthetic processes. (4) Wave-lengths 0.15 to 0.1μ, comprising an ultra-violet region which is little known.

Among the physical and chemical effects produced by ultra-violet light are many of practical value, affording quick tests for certain properties, and acceleration of certain chemical reactions. The sterilization of liquids such as water and milk, and of semi-solids like edible fats, is readily accomplished by ultra-violet rays. Exposure of only a fraction of a second under proper conditions is required for complete sterilization. Most dyes fade rapidly under treatment with ultra-violet light, and some remain fast. Fabrics like cotton, rubber, oil-cloth, etc., reveal in a comparatively few minutes the deterioration that otherwise would not become apparent for days in ordinary light. Numerous organic substances are bleached by its action.

Chemical reactions produced by ultra-violet light are many and varied. Chlorine derivatives of toluol are produced in greatly increased yields and without undesirable by-products if the reaction proceeds in the presence of ultra-violet rays. Other chlor-substitution organic products are formed with greater facility, in greater quantity, and of higher degree of purity if ultra-violet light enters into the reaction. The halogen elements generally seem sensitive to this force and enter into synthetic reactions rapidly under its influence. Cyanogen is converted into para-cyanogen, sulphur and phosphorus show allotropism, organic compounds undergo isomeric changes, hydrolytic reactions are accelerated, and numerous other changes occur under influence of ultra-violet rays.

The production of these rays in a manner suitable for application in the arts has been the subject of considerable invention. They are given off in concentrated form from a mercury-vapor lamp, but, since glass is impervious to them, it is necessary to construct the lamp of quartz if the rays are to be used.

An improved form of quartz mercury-vapor lamp which embodies new features in construction and application is manufactured by the R. U. V. Company, New York City. This lamp produces an ultra-violet component several times stronger than that yielded by other forms of quartz mercury-vapor lamps. The wave-lengths of its light have been measured as low as 0.18μ, indicating a high degree of activity according to Berthelot's classification given above.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

REVISED FORMULA FOR LUMINOSITY CURVE SOLUTION FOR PHYSICAL PHOTOMETRY.

By Herbert E. Ives.

SINCE the publication of a luminosity curve solution formula by Ives and Kingsbury, a large number of measurements have been made by Crittenden and Richtmyer by the visual (flicker) photometric method taken as the criterion in the writer's physical photometric studies. The result of this work of Crittenden and Richtmyer is to lead to a slightly different choice of composition for the test color solutions, which over a "4-watt" lamp should measure equal by the average eye. The originally published and revised test colors are:

Original	Revised
$CuSO_4$...53 grams to 1 liter of water	$CuSO_4$...57 grams to 1 liter of water
$K_2Cr_2O_7$..72 grams to 1 liter of water	$K_2Cr_2O_7$..72 grams to 1 liter of water

This change corresponds to a change of two per cent. in the relative transmissions.

In order to meet this new test color composition the luminosity curve solution formula has been empirically changed to give the ratio unity in the physical photometer, as follows:

Original luminosity curve solution		Revised	
$CuCl_2$	60 grams	$CuCl_2$	61.25 grams
$Co(NH_4)_2(SO_4)_2$	14.5 grams	$Co(NH_4)_2(SO_4)_2$	14.5 grams
K_2CrO_4	1.9 grams	K_2CrO_4	1.9 grams
Water to	1 liter	Water to	1 liter

The transmission of this new solution through the spectrum is probably very accurately represented by Kingsbury's formula, in which the values at the red end were purposely kept lower than the transmission of the original solution, the results of Crittenden and Richtmyer being known from correspondence. The work was interrupted before spectrophotometric values could be obtained.

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* Communicated by the Manager.

Occasion was taken to try the modification of this solution proposed by Coblentz and Emerson to represent the results of their determination of the equal energy spectrum luminosity curve. The value obtained with their solution for the ratio of yellow to blue transmission was 1.045 instead of unity. This may be explained by the fact that their determination of the luminosity curve was carried through, apparently for reasons of instrumental convenience only, at a much lower brightness than that used in the photometric study of the test colors by Crittenden and Richtmyer. Agreement of visual and physical methods of photometry is obviously dependent on the luminosity curve used in the latter being obtained under the conditions adopted for the former.

EXPERIMENTS ON THE BLACK BODY AT THE MELTING POINT OF PLATINUM AS A FIXED POINT IN PHOTOMETRY.

By Herbert E. Ives.

These experiments were intended to carry to practical realization the suggestions of Waidner and Burgess and the writer to utilize the melting point of platinum to establish a standard (not a unit) of luminous intensity. Attention was devoted to the effects of tension and thickness on the melting point, and to determining the best shape and dimensions for achieving the black body required.

It was found that lowering of the melting point, due to tension on the thin sheet metal employed, was insignificant for any tensions necessary to use in the suggested method of achieving the black body. No variation of melting point with thickness was found. These questions were tested by photometric criteria.

The acute-angled hollow wedge of sheet platinum used formerly was found much inferior as to uniformity of heating to a hollow cylinder of sheet metal, with a small slit opening parallel to the axis and viewed at an angle of about 20 degrees to the diameter passing through the opening.

This work was interrupted at the point where the practicability and precision of the method appeared to be established, but before data could be obtained with chemically pure platinum.

Using the same grade of platinum as that studied previously, whose melting point was determined as practically that of Hereaus platinum, the mean of several close determinations was 58.4 candlepower per square centimetre as the brightness of the black body at the melting point of platinum, in excellent agreement with the value obtained before (58.35).

This value, if used with Kingsbury's formula for the luminosity curve of the equal energy spectrum, and the value .00160 for the mechanical equivalent of light, is in harmony with the following selection of values for the physical constants involved.

$$\sigma = 5.72 \times 10^{-12}$$

$$C_2 = 14312$$

$$\text{Melting point of platinum} = 2037^\circ \text{ K } (1764^\circ \text{ C})$$

It is hoped to continue this work at a later date.

December 31, 1917.

Adjusting Watches to Temperature. J. THOMPSON, JR. (*The Horological Journal*, vol. 60, No. 714, p. 57, February, 1918.)—In the early days of watch- and chronometer-making, the compensation for changes of temperature was practically unthought of. If a person possessed a watch that would run and give him an approximate idea of the time of day, that was considered satisfactory and all that was necessary. As the methods of watchmaking advanced, certain watchmakers began to conceive of a plan to reduce the errors caused by temperature changes, and it remained for Harrison, a very clever English watchmaker, to devise one of the first means of compensation, consisting of a regulating arm made of brass and steel that would move with changes in temperature much the same as the compensating balances of the present day. The arm operated to move the regulator pins along the hairspring so as to slightly shorten the vibration in heat and lengthen them in cold, thus overcoming the effect of the changes in length of the spring.

This method was crude and unsatisfactory, even to the inventor, and was condemned by Julien le Roy, a noted French watch- and clock-maker, who abandoned the idea in favor of the compensating balance of brass and steel. These early balances were so satisfactory that they have undergone but slight changes in more than a hundred years. In any watch or chronometer, errors of time resulting from changes of temperature are caused by various other conditions than those of the balance and hairspring. Of these, the change in the fluidity of the oil is one of the most prominent, but the size of the balance as well as that of every other part of the watch is continually changing with the temperature. It is the office of the compensation to eliminate the errors of time from all these causes so far as it is possible to do so.

In the Waltham factory the watches are first run twenty-four hours at a temperature of 40° F., and the rate recorded. Next the watches are wound and reset, and after being allowed to run twenty-four hours at a temperature of 90° F. the rate is again recorded. From these rates the amount of adjustment of the screws on the balance wheel is estimated. After retiming, the test is a trial running and is not considered final even if the watch runs within the prescribed limits for its grade, as the balance does not attain its maximum compensation on first being exposed to extremes of temperature. The temperature adjustment is of extreme importance on account of its permanency, and with the same balance and hairspring need never be blamed for any but slight variations in the performance of a watch.

A New Method of Separating Materials of Different Specific Gravities. T. M. CHANCE. (*The Coal Age,* vol. 13, No. 19, p. 866, May 11, 1918.)—The separation of materials of different specific gravities by means of a fluid having a specific gravity greater than the lighter particles and less than that of the heavier particles has not been applied commercially or on a large scale to the separation of ores or to the washing of coal, the method being limited to laboratory experimental work or to laboratory determinations for the purpose of checking up the work of jigs, classifiers, and other types of concentrating appliances. A solution of zinc chloride has thus come into general use in the laboratory to separate coal, bony coal and slate for test purposes. Difficulties that are practically insuperable, however, have prevented the commercial development of the use of such solutions for making separations on a large scale, these difficulties being both physical and financial. The cost of the chemical used to make high-gravity solutions is usually prohibitive, and the freeing of the coal from all traces of the chemical is found to be practically impossible.

It has been found that a mechanical mixture of water and fine sand created and maintained by agitation will have sustention and therefore selection qualities similar to those of a real solution in which bodies having greater specific gravity will sink and those of less specific gravity will float. A mixture of sand and water can be used to produce a fluid mass having a specific gravity suitable for the separation of coal from its impurities. Fluid masses, having specific gravity high enough to float quartz, feldspar, limestone and other rocks, can be produced by using magnetic iron-ore sand and water instead of quartz sand and water. Other heavy materials can be used, such as ore concentrates of galena, metallic copper, etc., for producing fluid masses having very high specific gravities.

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Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
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Name	Appointment	Location
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Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R,	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, June 5, 1918.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 5, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following reports were presented for final action:

No. 2708.—The Waterbury Hydraulic Speed Gear. Recommended that the Elliott Cresson Medal be awarded, jointly, to Reynold Janney, of New York, N. Y., and Harvey D. Williams, of Washington, D. C., for the invention of The Waterbury Hydraulic Speed Gear.

No. 2714.—H. C. Snook's Improved X-Ray System. Report referred back to Sub-Committee for further consideration.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting Board of Managers, June 12, 1918*)

NON-RESIDENT

MR. JAMES A. FLYNN, Production Engineer, 112 Brilliant Avenue, Aspinwall, Pa.

CHANGES OF ADDRESS.

MR. G. EDWARD BARNHART, 413 West Jersey Street, Elizabeth, N. J.

MR. CALVIN BARWIS, in care Pennsylvania Railroad Company, Warren, Pa.

REAR ADMIRAL JOHN R. EDWARDS, U.S.N., Brown University, Providence, R. I.

PRIVATE ENOCH KARRER, 437 Engineers, in care Bureau of Standards, Washington, D. C.

MAJOR VICTOR LENHER, Chemical Service Section, N.A., War Department, 7th and B Streets, N.W., Washington, D. C.

MR. JOHN F. MCALLISTER, Hotel Vendig, Philadelphia, Pa.

Mr. I. F. Stone, 21 Burling Slip, New York, N. Y.

Mr. Francis R. Wadleigh, Emergency Fleet Corporation, 1528 Chestnut St., Philadelphia, Pa.

Mr. J. F. Warwick, in care Bethlehem Loading Company, May's Landing, N. J.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers. Transactions, vol. 9. 1916.

Boyd's Philadelphia Blue Book. 1918.

California State Mining Bureau. Annual Reports. No. 1 and No. 4. 1880, 1884.

Caven, R. M.—Carbon and Its Allies. 1917.

Engineering Index Annual, vol. 34. 1917.

Fraps, G. S.—Principles of Agricultural Chemistry. 1917.

Ketchum, M. S.—Design of Steel Buildings, and the Calculation of Stresses in Framed Structures. 1912.

Ketchum, M. S.—Structural Engineers' Handbook. 1914.

Lecornu, Leon.—Cours de Mecanique, vol. 1, 1914. Vol. 3, 1918.

McAdie, Alexander.—Principles of Aërography. 1917.

McShane, C. L.—Modern Locomotive Valves, and Valve Gears. 1917.

Parkinson, James.—Chemical Pocket Book; or Memoranda Chemica. 1802.

Roebuck, J. R.—Science and Practice of Photography. 1918.

Rogers, Allen.—Laboratory Guide of Industrial Chemistry. 1917.

Society of Chemical Industry, Reports of the Progress of Applied Chemistry, vol. 1. 1916.

Who's Who; An Annual Biographical Dictionary. London. 1918.

Wiley, H. W.—Food and Its Adulteration. 1917.

BOOK NOTICES.

Cours de Mécanique Professé a l'École Polytechnique, par Léon Lecornu, Membre de l'Institut, Inspecteur Général des Mines. In three volumes, 8vo, paper, sold separately. Volume I, vii + 536 pages with 281 illustrations, 1914, price, 18 francs; volume II, vi + 538 pages with 110 illustrations, 1915, price, 18 francs; volume III, vi + 667 pages with 211 illustrations, 1918, price, 25 francs. Paris, Gauthier-Villars et Cie.

Subordinate only to adequate training in mathematics, a thorough knowledge of analytical mechanics is the essential basis of a study of the physical sciences and their applications in various branches of technology, and a text on this important fundamental should embody a supreme effort of professional and pedagogical skill. As the author points out, while laying stress on the theorems of pure mechanics, it should be designed to develop an appreciation of material values, and, to a certain extent, serve as an introduction to the particular applications in which the student may specialize.

Addressed to students of a school representative of the highest standard of scholarships, Professor Lecornu's work is planned on these broad lines. It presents the subject on the solid foundation of the development of basic theorems at considerably greater length than is usually deemed needful in many of our engineering courses, and is of a type suitable to the investigator as well as to the analytical practitioner.

The first two volumes cover kinematics, statics, dynamics, elasticity, and the mechanics of fluids. The third volume is devoted to the applications, resistance of materials, hydraulics, thermodynamics, theory of machine, and the elements of aviation. These divisions of the subject, the author states, are not now included in the course in mechanics of the École Polytechnique, but have been added in anticipation of radical changes that may be expected in technical education to meet the industrial competition of post-war conditions, when the attainment of material accomplishment rather than scholarly attainment will have become imperative. The work constitutes essentially the theoretical part of a course in mechanical engineering in which the study of fundamental principles has been dwelt upon as exhaustively as practicable limitations of time permit.

Although intended as a text, a work covering such an extensive field should prove valuable for reference and for that reason the omission of an index is to be regretted. However, very full tables of contents partly compensate for this omission. As is usual with the products of its widely known publishers, the typographical features of the work are of a high order of excellence. LUCIEN E. PICOLET.

THE CHEMICAL ANALYSIS OF IRON: A COMPLETE ACCOUNT OF ALL THE BEST KNOWN METHODS FOR THE ANALYSIS OF IRON, STEEL, PIG-IRON, ALLOY METALS, IRON-ORE, LIMESTONE, SLAG, CLAY, SAND, COAL AND COKE. By Andrew Alexander Blair. Philadelphia, J. B. Lippincott Company, 1918. Eighth edition, 318 pages, illustrations. 8vo. Price, $5.00.

Since the first edition of this work appeared, about 30 years ago, it has held a conspicuous place as *the Standard,* both in colleges and in industrial works. The fact that it has now passed through no less than eight editions is prima facie evidence that it has kept pace with the march of progress and a truly wonderful march this has been!

"Alloy Steels" were unborn when the earlier editions appeared. Tungsten, Molybdenum, Vanadium, etc., were rare elements found only, if at all, in minute specimens in cabinets of minerals and metals. All of these now constitute very important alloys with iron and are classed under the generic name of Alloy Steels. There were no standard methods of analysis of these alloys recorded in any one book so far as the reviewer knows, before they appeared in the work under discussion. Even fifty per cent. ferro-silicon, now so familiar to iron and steel metallurgists, was not produced practically until after the development of electric furnaces and it is within the memory of living men when eighty per cent. ferro-manganese was a novelty. Some of these alloys are insoluble in the usual acid solvents for iron compounds, hence entirely different methods of preliminary treatment of samples for analysis were required. Various original methods were devised by different investigators toiling in their laboratories and gradually formulæ for rapid determinations were evolved for use in daily work in industrial establishments.

Examination of the eighth edition of "The Chemical Analysis of Iron" reveals not only the methods that the writer has already seen in print, but others which are entirely new to him. He therefore has no hesitation in pronouncing this work thoroughly up to date. A. E. OUTERBRIDGE, JR.

PUBLICATIONS RECEIVED.

How to Become a Wireless Operator: A Practical Presentation of the Theory of Electrical Waves, Their Propagation, and Their Adaptation to Wireless Communication, Including Simple and Clear Instructions How to Operate Wireless Devices and How to Comply with Government Requirements for Operators, by Charles B. Hayward. 312 pages, illustrations, 8vo. Chicago, American Technical Society, 1918.

Machine Design: A Manual of Practical Instruction in Designing Machinery for Specific Purposes, Including Specifications for Belts, Screws, Pins, Gears, etc., and Many Working Hints as to Operation and Care of Machines, by Ernest L. Wallace, B.S., E.E. 164 pages, illustrations, 8vo. Chicago, American Technical Society, 1918.

Portland Cement Association: Catalogue of Books, Periodicals and Pamphlets in the Library. 59 pages, 8vo. Chicago, Association, 1918.

Athenæum Subject Index to Periodicals, 1916: Issued at the Request of the Council of the Library Association. Science and Technology, Including Hygiene and Sport. 162 pages, quarto. London, The Athenæum, 1918. Price, 10 shillings net.

U. S. Coast and Geodetic Survey: Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory, Near Tucson, Arizona, 1915 and 1916, by Daniel L. Hazard, Chief, Division of Terrestrial Magnetism. 101 pages, plates, quarto. Washington, Government Printing office, 1918. Price, 25 cents.

Successful Trial Trip of the Reinforced Concrete Cargo Steamship Faith. 15 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1918.

U. S. Department of Agriculture: Bulletin No. 606. Professional Paper. Relative Resistance of Various Hardwoods to Injection with Creosote, by Clyde H. Teesdale, in charge, Section of Wood Preservation, and J. D. Maclean, Assistant Engineer in Forest Products. 36 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1918.

U. S. Bureau of Mines: Bulletin 149. Bibliography of Petroleum and Allied Substances, 1915, by E. H. Burroughs. 147 pages, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, February, 1918. List of Permissible Explosives, Lamps, and Motors Tested Prior to March 31, 1918, compiled by Albert H. Fay, 21 pages, 8vo. Technical Paper 162: Initial Priming Substances for High Explosives, by Guy B. Taylor and W. C. Cope. 32 pages, 8vo. Technical Paper 193: Quarry Accidents in the United States During the Calendar Year 1916, compiled by Albert H. Fay. 58 pages, 8vo. Technical Paper 202: Metal-mine Accidents in the United States During the Calendar Year 1916. Compiled by Albert H. Fay. 91 pages, 8vo. Washington, Government Printing Office, 1918.

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SOME CHARACTERISTICS OF AMERICAN COALS IN BY-PRODUCT COKING PRACTICE.*

BY

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Before taking up the more technical phase of the subject it may not be amiss to discuss some of the broader relations of the American by-product coke industry.

The bulk of our material civilization during the past century has been built up by iron and energized by coal. These two are linked by coke. Next to the substitution of the shaft furnace for the old forge or bloomary, the greatest improvement in the iron industry was the substitution of coke for charcoal. It is difficult to realize that this important step was taken, with many misgivings, less than two centuries ago in England and less than seventy years ago in America. It was between 1730 and 1735 that Abraham Darby[1]—after six sleepless nights, it is related—succeeded in making the first cast of iron from a coke-fed furnace in England. Other sporadic efforts had undoubtedly been made previous to that time, but it was then that a continuous development of the coke industry in England may be said to have started. On the continent of Europe the regular use of coke was not introduced until a number of years later, while in

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* Presented at the stated meeting of the Institute held Wednesday, March 20, 1918.

[1] Percy's Metallurgy (1864), p. 886.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

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America it was not until 1850[2] that it began to exert an appreciable influence upon the manufacture of pig iron. In 1849 there was not a single coke furnace in blast in this country. Immediately after the Civil War, however, the demand for coke underwent a phenomenal development, at a rate which shows no signs of slackening. The coke industry is now truly regarded as an integral and vital part of the iron and steel industry. Not more than 110,000 tons[3] of coke were consumed in the production of pig iron in 1865. Twenty-five years later, in 1890, the annual consumption was about 10,000,000 tons. Fifty years later, in 1915, 36,700,000 tons of furnace coke and 1,700,000 tons of foundry coke were consumed. Last year (1917) the consumption of furnace and foundry coke was probably in excess of 50,000,000 tons. Thus in the past two years alone the industry has increased even more than in the phenomenal twenty-five-year period preceding 1890.

Up to about 1893 the country was dependent upon beehive coke alone. Now please note that so soon after the establishment of the industry, when it had already attained an enormous growth and had so revolutionized the iron industry that coke instead of charcoal was recognized as the standard fuel for the blast furnace, even at this time men could foresee within a comparatively short period the same extinction that had virtually befallen the charcoal industry. Only a narrow range of coals can be used to make good metallurgical coke in the beehive oven. The supply of such coals was rapidly approaching exhaustion. In Belgium and Germany the exhaustion of beehive coals had begun to force the introduction of the by-product oven, irrespective of any other economic considerations.

In a paper read a year ago, before The Franklin Institute, by Mr. C. J. Ramsburg,[4] there were brought forward three facts that are of great importance in this connection:

> 1. For every ton of coke made in the by-product oven there is saved in fuel value alone the equivalent of 825 pounds of coal.

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[2] "Iron in All Ages," Swank, p. 370.

[3] Figures throughout this paper are in net tons, except where otherwise indicated.

[4] JOURNAL FRANKLIN INSTITUTE, vol. 183, 1917, p. 391.

> 2. For every ton of coke made in the by-product oven and applied to blast-furnace purposes there is a direct saving of 482 pounds of coal (200 pounds wasted in beehive oven + 282 pounds saved in blast furnace, due to the superiority of by-product coke).
>
> 3. The by-product oven, by reason of its great flexibility of control, enables us to make good metallurgical coke from a very wide range of coals.

The development of the by-product coke oven is as vital to the modern iron and steel industry as was the substitution of coke for charcoal. For all practical purposes it has indefinitely prolonged the life of this great business, because the new reserves of coking coal that it has opened up and that are actually in sight are far more than sufficient to take care of the estimated iron ore resources of the world.

The phase of any industry that vitally interests us nowadays is its relation to winning the war. Industrially and scientifically, only those subjects that have a bearing on this great problem should occupy our attention at this time. Let us consider this aspect of the by-product coke industry. The vital connection of its main product—coke—with the iron and steel industry would alone suffice to place it in the front rank of the "essentials"; but, more than this, its by-products are recognized as being indispensable to the conduct of modern warfare. One need only mention ammonia, the indispensable source of ammonium nitrate and the potential source of nitric acid; benzene; phenol; picric acid; naphthalene with its mono-nitro derivative; cresol for antiseptic surgery; and, finally, toluene and trinitrotoluene, which is veritably the super-necessity of up-to-date artillery. Besides these, there are a host of coal-tar derivatives, employed for military and surgical purposes, which it would be very difficult to do without. The by-product coke oven is by far the largest source of these materials. Its relation to our toluene supply is of particular concern. Trinitrotoluene (T.N.T.), which can only be produced from toluene, is the only known high explosive that combines the merits of safety, reliability, and extraordinary power with the requisite capability of large-scale production. Notwithstanding the fact that we have one or two other large sources of toluene, it is unquestionably true that the by-product coke oven is by far the most important producer. Moreover, it is the one and only source that can be absolutely depended upon to make toluene of the highest purity—especially in respect to freedom from paraffins.

All the facts, when carefully studied, justify the assertion that the by-product coke industry is one of the most vital to the winning of the war. So essential is this industry to the conduct of modern warfare that the striking power of each nation may, to a great extent, be measured by its supply of the by-products of coke. The extent of German preparation and advantage in this respect warrants our earnest consideration.

It is difficult to obtain trustworthy statistics as to the actual amount of by-product coke made in the various countries of the world. Fortunately, however, we have very reliable figures[5] for ammonium sulphate. Such figures as have been tabulated for the production of this material from coke ovens may be taken as an index to the extent of by-product recovery practised in each country.

In 1907 Germany produced 282,700 tons of ammonium sulphate from by-product coke ovens. This was more than the production from the same source *in all other countries combined.* In the same year the United States produced 68,970 tons of ammonium sulphate from by-product coke ovens. In 1913 the German industry produced 523,114 tons, which exceeded by over 100,000 tons the combined production of the coke ovens of the United States, England, France, Belgium, and Holland. The seizure of Belgium and northern France probably gave the Central Powers an advantage in coke-oven resources equivalent to an annual production of 100,000 tons of ammonium sulphate more than the combined production of the Entente Allies plus all the neutral countries of the world. Roughly, this advantage is equivalent to the product of coking 10,000,000 tons of coal. The military significance of these figures is not difficult to realize.

The fact that in the short space of three years great steps have been taken towards equalizing this advantage is an everlasting credit to American enterprise. The year 1917 showed a gain of more than 10,000,000 tons of by-product coke over the year 1914, which is probably equivalent to an increase of 14,000,000 tons of coal used in by-product ovens. Ovens now under construction have an additional capacity of over 10,000,000 tons of coal per annum.

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[5] Annual reports on sulphate of ammonia prepared by the American Coal Products Company. The original figures in the report for 1914 are given in metric tons, which are here transposed to net tons.

Even under the most favorable conditions, however, the American production of by-product coke in 1918 will be less than the German production at the beginning of the war. The total German production for 1912 was about 32,000,000 and for 1913 about 35,000,000 tons, while the United States produced 22,000,000 tons in 1917 and will probably produce 27,000,000 tons in 1918. When it is recalled that we are still making beehive coke at the rate of 33,000,000 tons per year—nearly as much as the entire German production in 1913—it will be seen that there is still much work to be done.

In fact, it must be admitted that the by-product oven has so far accomplished little more than taking care of the natural increase of coke production in America. It is a mistake to suppose that we have really done much toward abolishing the beehive oven. The amount of beehive coke made per year has undergone no appreciable diminution since 1906.

These 33,000,000 tons of beehive coke represent the loss of the following products:

Table I.

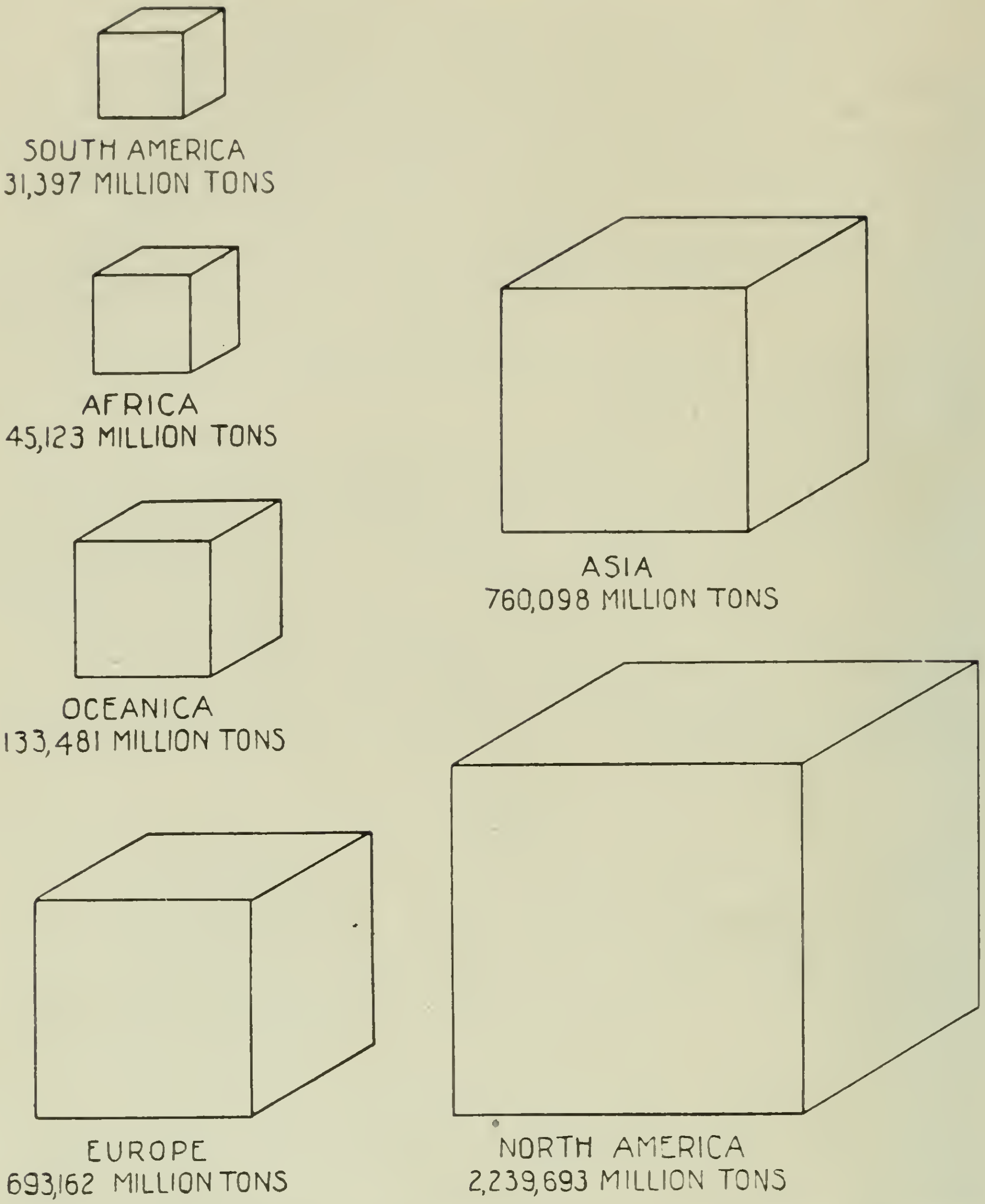
Coke	2,475,000 tons.
Tar	396,000,000 gallons.
Ammonium sulphate	545,000 tons.
Surplus gas	300,000,000,000 cubic feet.
Benzene	82,500,000 gallons.
Toluene	20,000,000 gallons.

Let us consider very briefly what these figures mean.

Two and one-half million tons of coke per year, which is based upon the loss in the beehive oven alone and does not take into account the large saving due to superiority of by-product coke in metallurgical practice, would keep fifteen 450-ton blast furnaces in continuous operation, or would supply the entire foundry business of the United States and leave over three-quarters of a million tons available for domestic purposes.

Four hundred million gallons of tar would, if used for fuel purposes alone, be equivalent to 2,200,000 tons of coal. It would supply enough fuel to produce 10,000,000 tons of open-hearth steel—which would fill the total estimated yearly requirements of

Fig. 1.



Bituminous Coal Reserves of the World Continents in Million Tons Metric.

Production—1910.

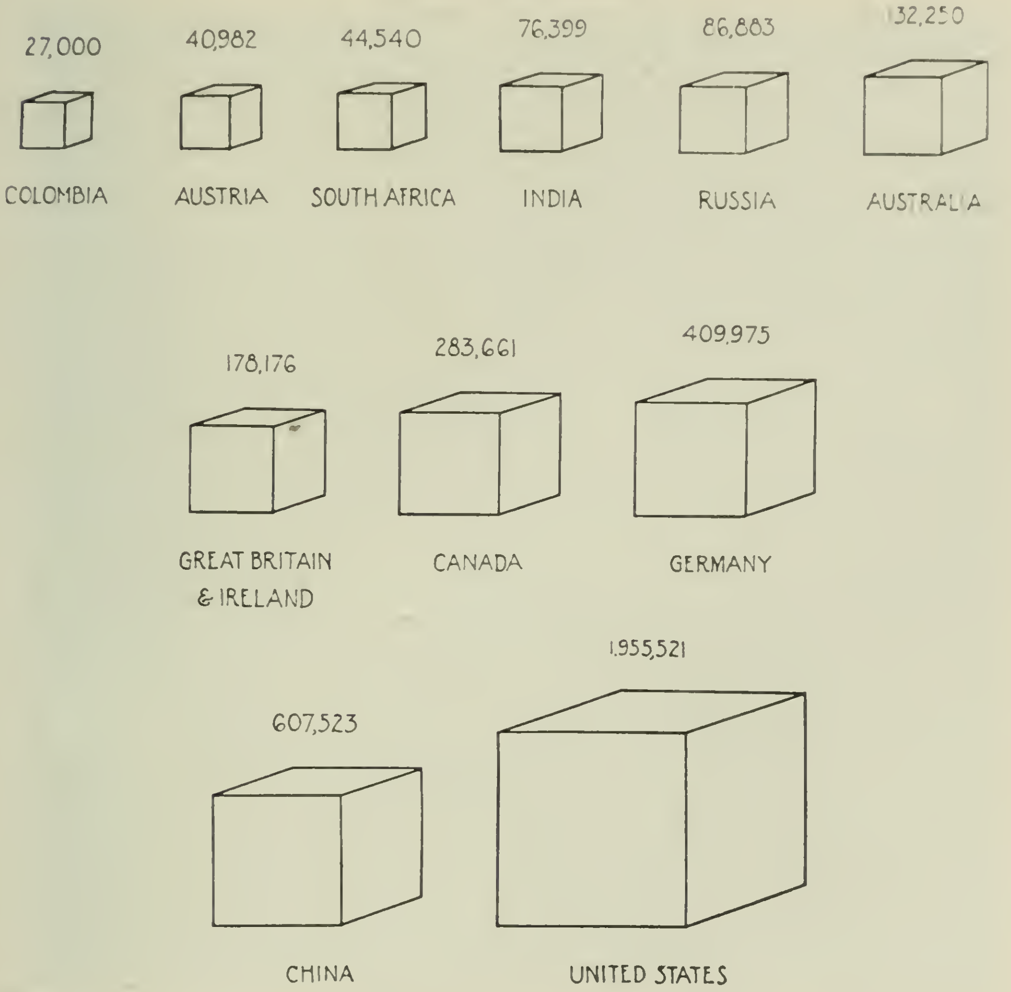
	Million tons		*Million tons*
Australia	10.0	Great Britain	264.5
New Zealand	2.23	Spain	3.55
China	14.59	France	38.57
India	12.09	Belgium	23.13
Japan	14.79	Germany	221.98
South Africa	5.5	Austria-Hungary	38.0
Canada	13.01	Italy	0.40
United States	445.81	Sweden	0.21
Mexico	2.45	Russia	24.57

Other countries .. 8.0 million tons

the United States and its Allies for steel for military purposes.[6]

Five hundred and forty-five thousand tons of ammonium sulphate are nearly equivalent to the entire annual production of the German Empire just prior to the war. This annual waste of valuable ammonia would furnish about 438,000 tons of nitric acid. A discussion of what this means from a military standpoint is not my purpose, but it would be of interest, in passing, to note that the estimate made previous to the war, by military authorities, for the annual nitric acid requirements of this country in case of war was 180,000 tons.

FIG. 2.
MILLION TONS METRIC.



Assuming the above quantities of coal to be distributed in each country in a single solid seam 6 feet thick, the respective coal-bearing area would compare as shown in figure 2 A:

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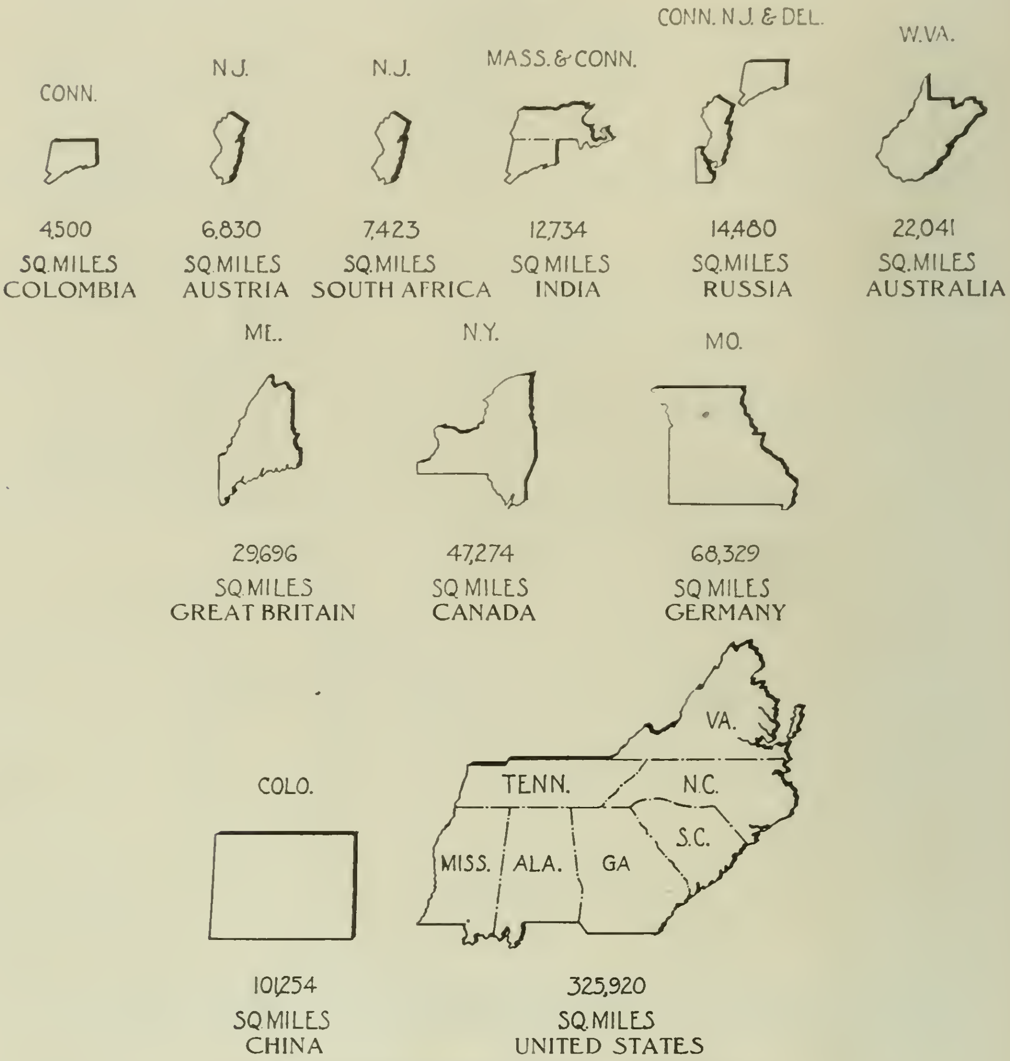
[6] *Iron Age*, January 3, 1918, p. 57—estimate for 1918.

From the standpoint of food supply this is even a more serious proposition. The permanent loss every year of more than half a million tons of ammonium sulphate—one of the most important nitrogenous fertilizers—might well arouse solicitude at a time when every effort is being made to increase our crop production. By ordinary agricultural practice about 100 pounds of ammonium sulphate are used per acre of cultivated land. We are therefore *burning up* every year in the beehive ovens enough nitrogen to fertilize 11,000,000 acres. It has been thoroughly demonstrated that the application of 100 pounds of ammonium sulphate to an acre of average wheat land (producing normally, say, 20 bushels) will increase the yield by about 8 bushels. Our wasted fertilizer

Fig. 2A.

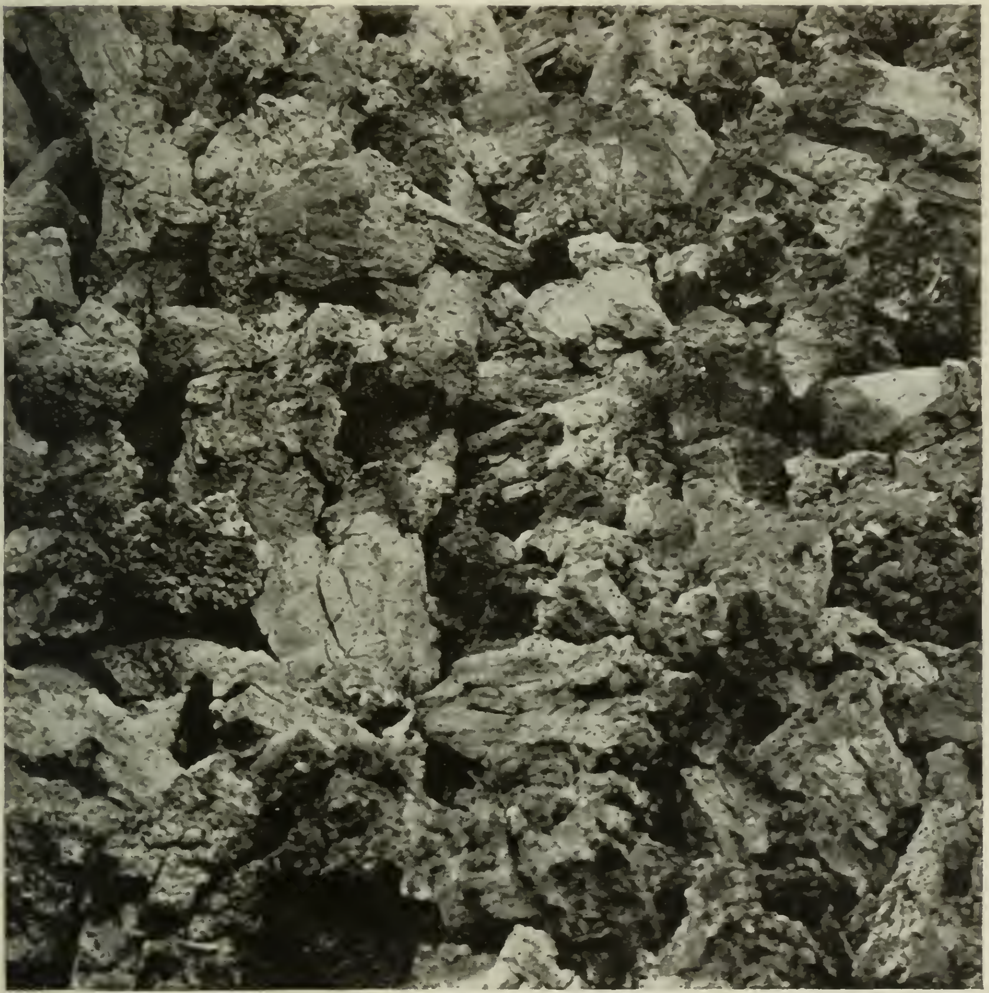


Comparative Reserves of Bituminous Coal.

would therefore be capable of increasing our wheat production by 87,000,000 bushels a year without additional labor.

Three hundred billion cubic feet of gas are nearly equivalent to the amount of natural gas consumed for industrial purposes in the states of Pennsylvania, Ohio, and West Virginia, which are the three largest consumers of natural gas in the Union. The diminution of the natural gas supply is a matter of grave concern in many important industrial centres, and by-product coke oven gas is undoubtedly one of the most promising sources of relief. The same piping and appliances now used for natural gas can with insignificant changes be used for coke-oven gas, and the

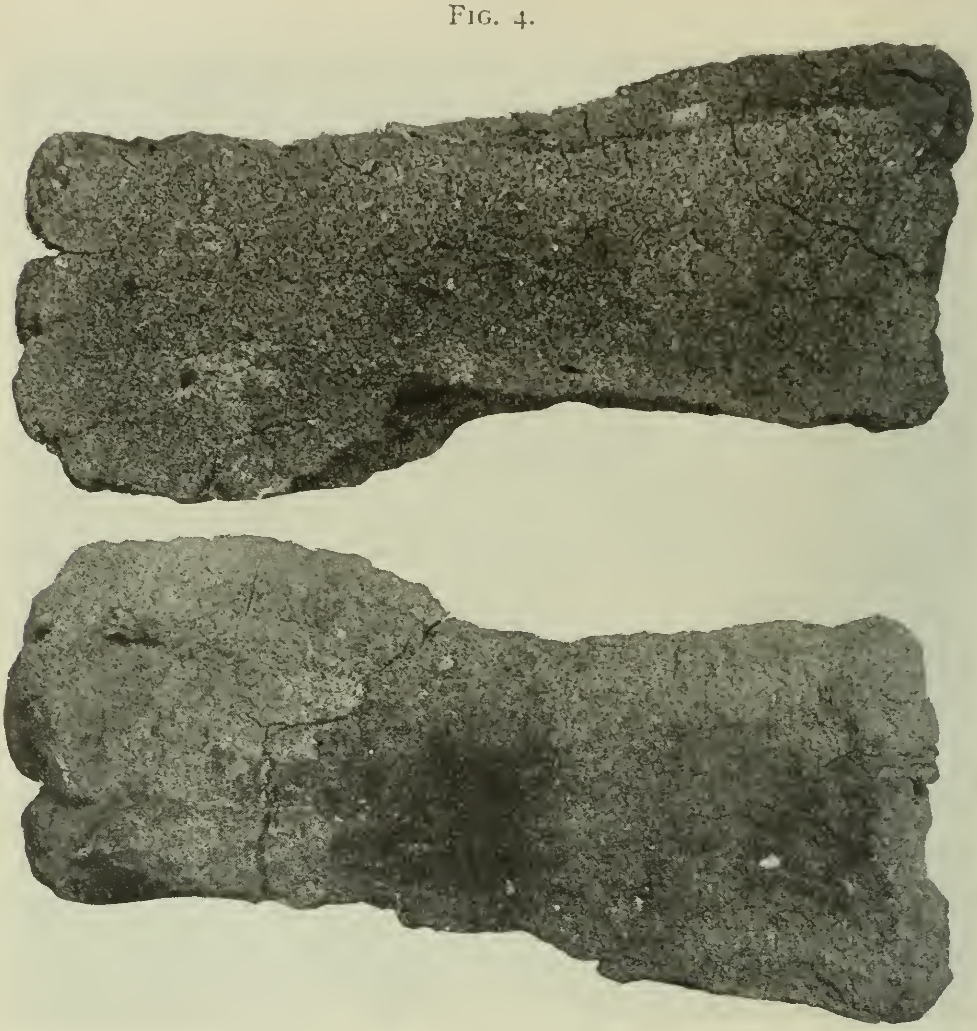
Fig. 3.



Coke made from Pittsburgh seam coal (Allegheny County, Pa.), mixed with 20 per cent. Elkhorn seam coal (Kentucky).

great benefit that would result from obviating the radical and expensive alterations of equipment otherwise necessary hardly needs to be pointed out. A value of 8 cents per thousand cubic feet for the coke-oven gas is a conservative figure from a natural gas standpoint, and would make the loss amount to $24,000,000 a year for this product alone.

Fig. 4.



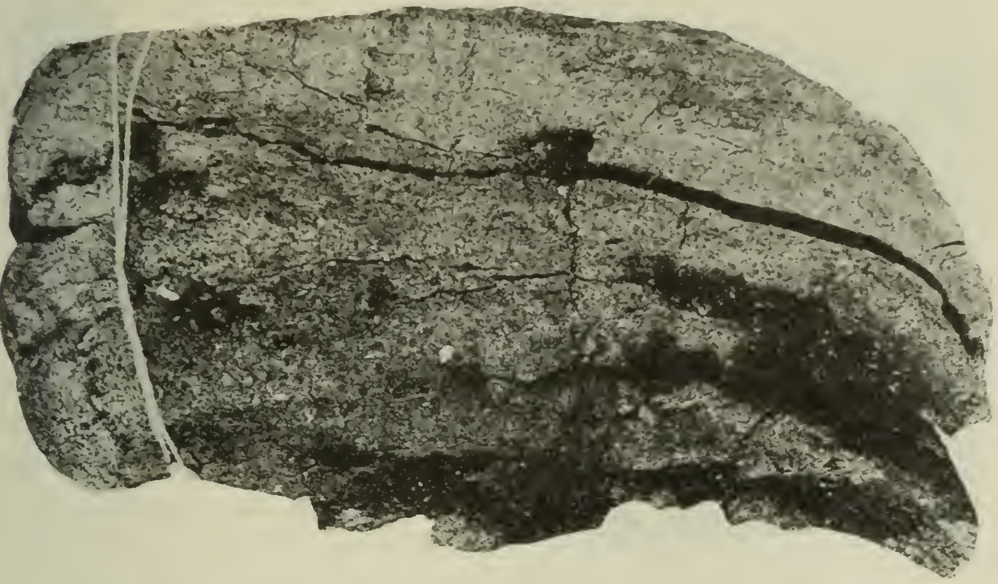
Block of typical coke from coals of Pittsburgh district. (Slightly less than half-size.)

Eighty-two million gallons of benzene would be of great value in replacing or supplementing gasoline as a special motor fuel for military purposes, to say nothing of its application to making picric acid, an important high explosive. One hundred gallons of benzene are equivalent, in efficiency, to 115 gallons of gasoline; for any sort of military vehicle of limited fuel-carrying capacity this is an important fact. Eighty-two million gallons of benzene would, if used for such purposes, effect a saving of about 12,000,000 gallons of gasoline.

Twenty million gallons of toluene would furnish enough T.N.T. to make 100,000,000 3-inch shells—quite a formidable argument.

Military values are what count nowadays, and one cannot estimate military values in terms of dollars and cents. Yet, for sake of completeness, we may sum up this situation in terms of very conservative *money* values under normal conditions.

FIG. 5.



Coke from 100 per cent. Illinois coal (District 6, Bed 6). (Note pebbly seam.)

TABLE II.

2,475,000 tons coke at $3.80	$9,405,000
396,000,000 gallons tar at 3½ cents	13,860,000
545,000 tons ammonium sulphate at $60	32,700,000
300,000,000 M. cubic feet gas at 8 cents	24,000,000
102,500,000 gallons motor fuel[7] at 15 cents	15,375,000
	$95,340,000

It is important to realize that this annual sum total of nearly $100,000,000 worth of the country's natural resources is not merely going unutilized every year, but is absolutely destroyed—

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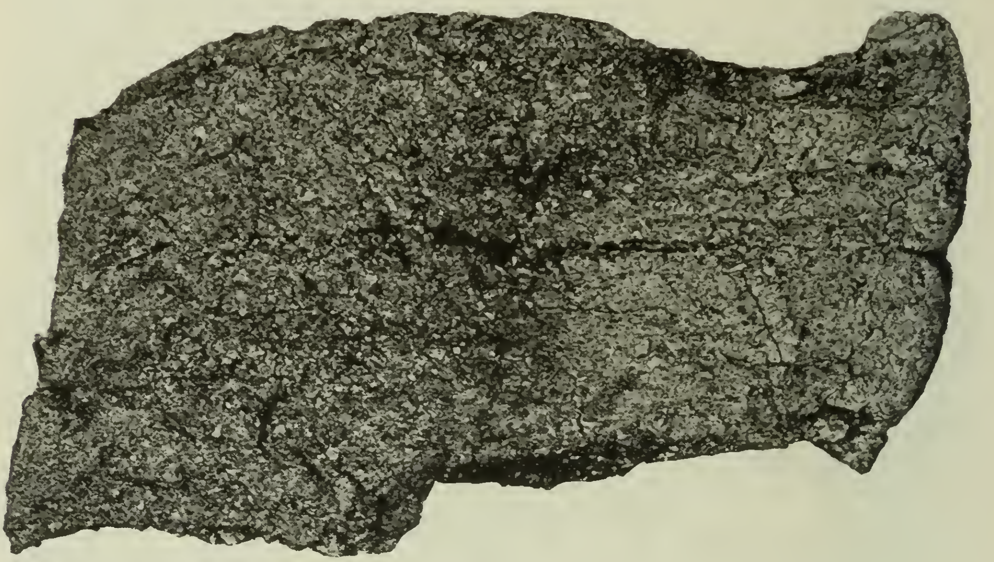
[7] Including only benzene and toluene. If all the available light oil constituents were included we would have at least 120,000,000 gallons motor fuel.

gone without the slightest possibility of recovery. It exceeds the value at the ovens of all the *coke* made in the United States in *1914*. In comparison with this gigantic waste, the cost of replacing the antiquated beehive with modern by-product recovery apparatus sinks into insignificance; even at present prices the replacement could be accomplished for less than $300,000,000. The war is costing the United States about $30,000,000 per day. This rate of expenditure would pay for the abolition of every American beehive oven in ten days.

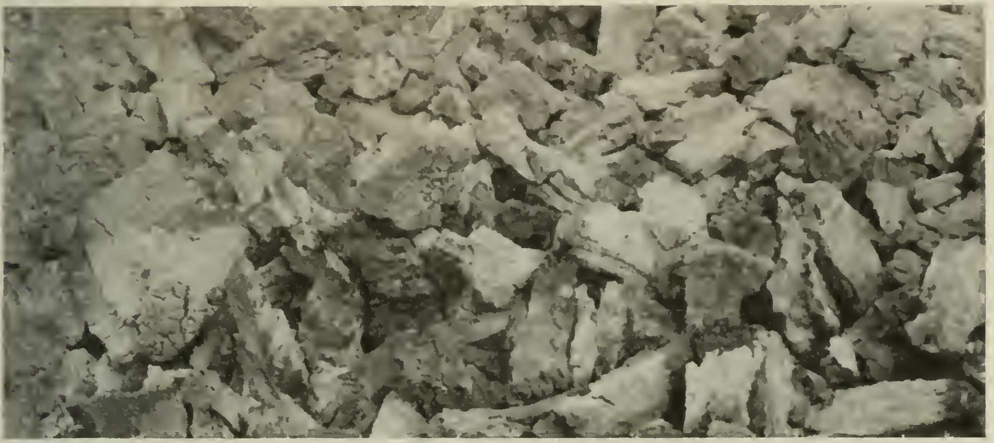
Fig. 6.



Coke from 100 per cent. Illinois coal (District 7, Bed 6).

Perhaps we are departing too far from the scope of what was intended to be a technical paper, but this phase of the subject is one that vitally concerns all of us at the present moment, and every possible agency should be interested and engaged in accelerating the change of the industry to the modern basis. The principal—and probably the only important deterring—factors are the present high cost of material and labor and the difficulty, under present conditions, of financing the expensive plants required. There is a rather strong temptation—which must be thoroughly understood and guarded against—to resort to cheaper forms of construction that have been tried and found wanting in the past, and which, if yielded to, will only discourage and delay the complete establishment of the industry. It would seem that the government might well assist in furnishing or reinforcing the capital necessary for a wholesale and immediate eradication of the beehive oven. The immediate practical, military benefits would be a sufficient argument, aside from the permanent conservation and the assured stability of the industry. Any development that can increase our wheat crop by nearly 90,000,000 bushels per year, that can more than double our material for high explosives, that is absolutely necessary in order to ensure to America and its Allies an unquestioned superiority in modern munitions, should be encouraged and hastened with every possible facility.

FIG. 7.



Coke made from unmixed coal, Pittsburgh seam, Lower Connellsville district, Fayette County, Pa.

Nor must it be forgotten that the beehive oven is not the only spendthrift of the important by-products of coal. The householder who burns a hundred tons of Pittsburgh coal in the winter months is likely, while standing aghast at the "Crime of the Beehive Oven," to forget that he himself is accessory in what is in the aggregate a greater crime. Table III, compiled from the statistics of the United States Geological Survey for the year 1915, shows the distribution of the coal produced in the United States.

Every encouragement should be given to the use of coke, gas, and briquetted fuel, which not only are important in national conservation, but are intrinsically cleaner, more economical, and more convenient.

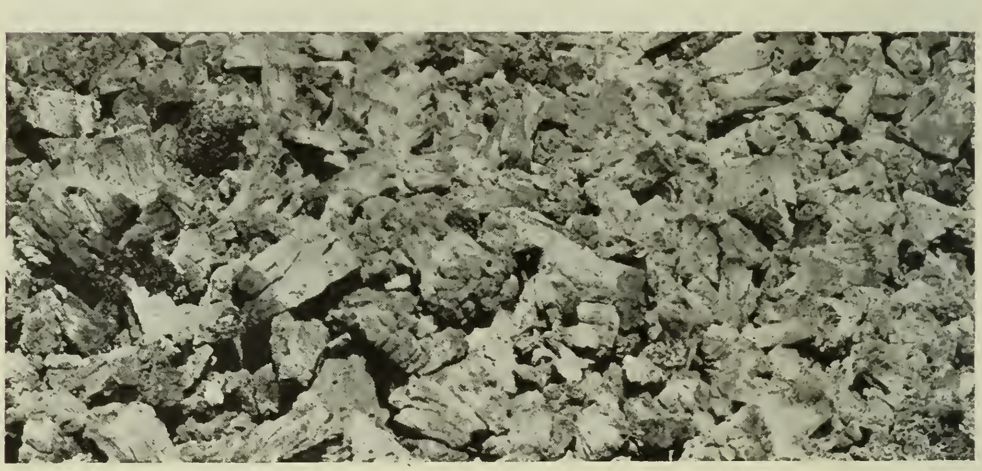
TABLE III.

Consumption of Coal and Lignite in the United States in 1915.

(M. R. Campbell, U. S. Geological Survey, Professional Paper 100-A.)

	Net tons.	Per cent. of total.
Railroad fuel	122,000,000	28
Steamship fuel	10,700,000	2.3
Beehive coke	42,300,000	9.3
By-product coke	19,500,000	4.3
Coal gas	4,600,000	1.0
Domestic and small steam trade	71,300,000	16.0
Industrial steam trade	143,800,000	33.0
Exported	18,800,000	4.0
Used at mines	9,800,000	2.0
Special uses	700,000	0.1
Total	443,500,000	100.0

FIG. 8.



Coke from unmixed coal, Pittsburgh seam, Westmoreland County, Pa. Made in wide oven. Somewhat overcoked.

All such considerations, vital as they may seem to the needs of the present moment, are in a larger sense dwarfed by the significance of America's enormous preponderance in reserves of coking coals. These are such as to ensure the stability and normal growth of the industry for many centuries in a sense that is true for no other country. The statistics graphically presented in Figs. 1 and 2 have been drawn up from the elaborate report of the Twelfth International Geological Congress on the Coal Resources of the World. Of course, the limitations of all such figures may readily be recognized, but they serve very well as a practical working basis on which to estimate important economic relations.

The figures for bituminous coal may be taken as a *comparative* index of the reserves available for making coke. It is the by-product oven that makes this broad generalization possible. Consider, with these statistics, the supplementary figures in Table IV for the principal iron reserves of the world, compiled by Edwin C. Eckel.[8] It needs no prophetic imagination to foresee that the future of the vast industries that are based on these two materials must largely rest with America, and her duty to conserve such resources becomes more than a local necessity; it is an international obligation.

TABLE IV.

Principal Iron Ore Reserves of the World.

District.	Minimum.	Maximum.
Lake Superior Region	2,000,000,000	2,500,000,000
Southern red ores	1,500,000,000	2,000,000,000
Texas brown ores	600,000,000	1,000,000,000
Other Southern ores	500,000,000	750,000,000
Northeastern States	300,000,000	600,000,000
Western States	300,000,000	700,000,000
Total United States	5,200,000,000	7,550,000,000

Continent.	Annual ore tonnage.	Equivalent tons metallic ore.
North America	14,710,000,000	6,455,000,000
South America	8,000,000,000	5,000,000,000
Europe	12,032,000,000	4,733,000,000
Total	34,742,000,000	16,188,000,000

It may be of interest to survey the present distribution of the by-product coke industry in America, and the way in which the various coal fields are being utilized.

By-product coke is now being made in the following states: Massachusetts, New York, New Jersey, Pennsylvania, Maryland, West Virginia, Alabama, Kentucky, Michigan, Indiana, Illinois, Wisconsin, Missouri, Minnesota, Tennessee, and Washington. Plants are also being built by the Koppers Company in Colorado and Rhode Island—eighteen states in all. Of these, only six—Alabama, Colorado, Ohio, Pennsylvania, Tennessee, and West

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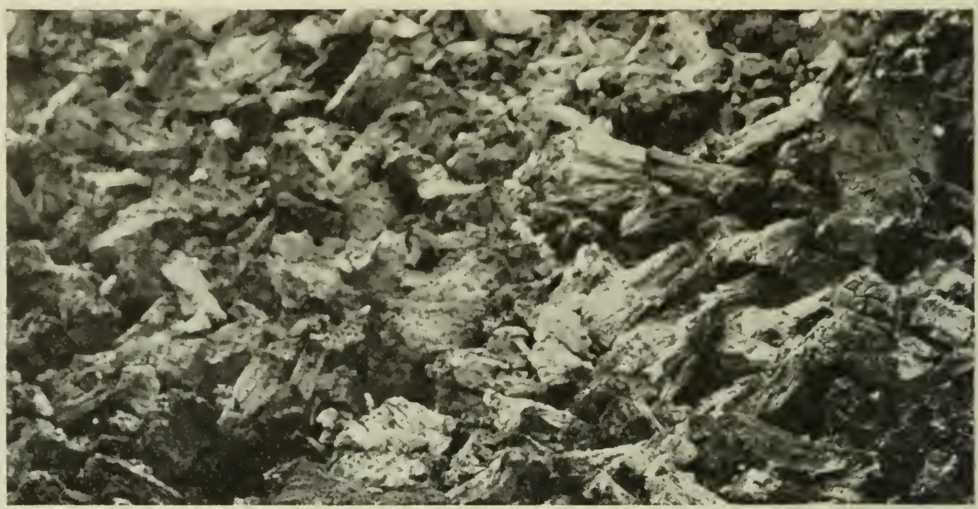
[8] *Iron Trade Review*, January 15, 1914.

Virginia—were coke producers of magnitude before the advent of the by-product oven. Together with this tendency to distribution, there is also an effect of concentration which is important. The effect in transplanting the business of coke manufacture from more or less secluded mining districts to important industrial centres is very marked. Two-thirds of the by-product coke producing capacity of the United States (including ovens under construction) is located within two hours' ride of one or another of five large cities: Chicago, Pittsburgh, Cleveland, Detroit, and Birmingham. The amount of by-product coke capacity in these five metropolitan districts exceeds the total coke (beehive and by-product) made in the United States in 1900.

Fig. 9.



Coke from unmixed coal, Pittsburgh seam, Marion County, W. Va.

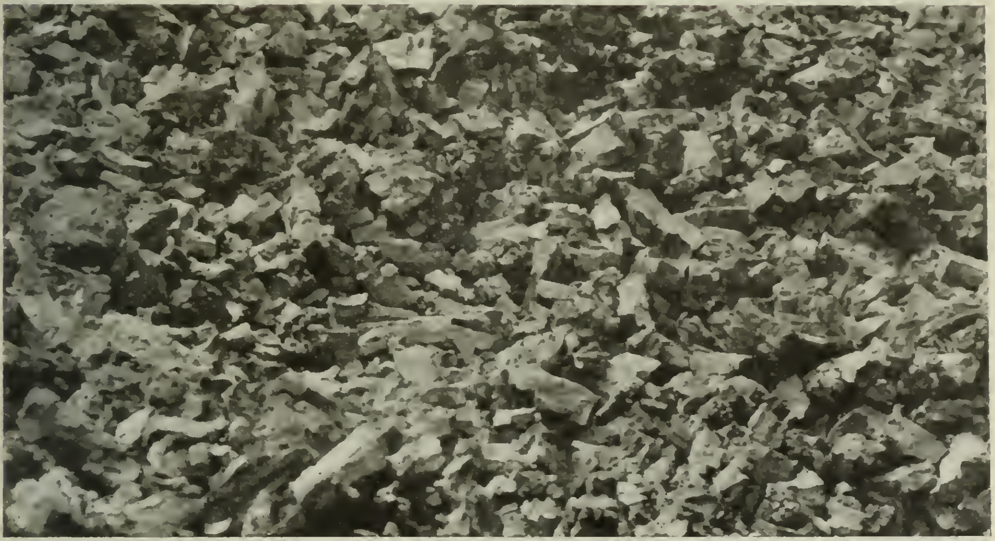
The intensive concentration of plant capacity made possible by the by-product coke oven is especially noteworthy. A striking example is the plant being built by the H. Koppers Company for the Carnegie Steel Company at Clairton, Pa. This plant, the largest in the world, will soon be put into operation with 640 ovens, having a capacity of 4,000,000 tons of coal per year. The plans provide for an extension of this plant to a total of 24 batteries of 64 ovens each. Some data as to the capacity and production of such a plant are as follows:

Annual Capacity of 1536 Ovens.

Coal	9,600,000 tons.
Coke	6,720,000 tons.
Tar	80,640,000 gallons.
Ammonium sulphate	110,880 tons.
Surplus gas	60,480,000,000 cubic feet.
Benzene	16,800,000 gallons.
Toluene	4,032,000 gallons.

This great plant, when completed, will have a coking capacity equivalent to 11,200 beehive ovens (one 12-foot beehive oven producing 600 tons of coke per year). In ordinary double-row construction (120 beehive ovens to a block 900 feet long) this would make 16 miles of beehive ovens. The by-product plant, including some vacant space, is only 1500 yards long and 1200 yards wide.

FIG. 10.

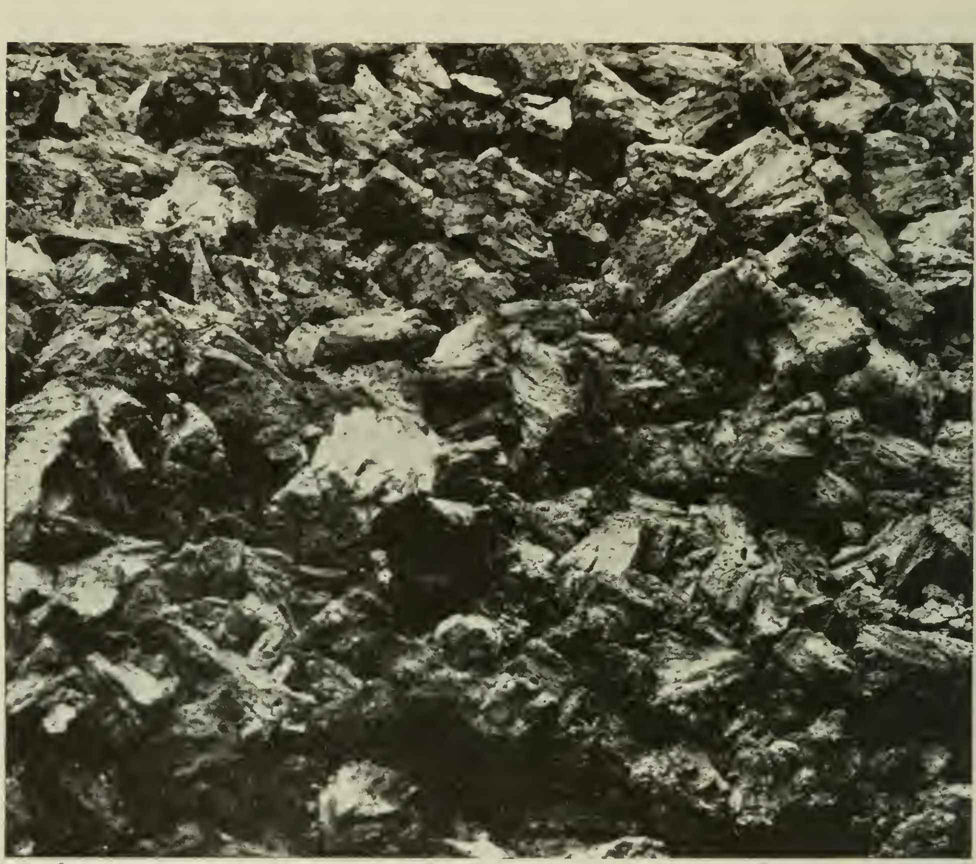


Coke from unmixed coal. Lower Kittanning seam, Fayette County, Pa.

The sources of the coal now being used for by-product coking are remarkably localized. The great bulk of the supply comes from the bituminous and semi-bituminous beds of the Appalachian trough as mined in Pennsylvania, Virginia, West Virginia, Alabama, and eastern Kentucky. Although some by-product coke has been made from Illinois and Indiana coals, and an important plant will soon begin operation upon Colorado coals, the enormous reserves of good coking coals in the interior, Rocky Mountain, and Pacific coast provinces have scarcely been touched by the by-product oven in a commercial sense.

The present tendency is to use less of the expensive semi-bituminous coals—Pocahontas, Somerset, etc.—and to coke mixtures containing much larger percentages of bituminous coals, the volatile matter in such mixtures being from 30 to 35 per cent. The percentage of low volatile coal runs in usual practice from 15 to 30 per cent. Very fortunately it happens that not only do such high volatile mixtures produce larger recoveries of by-products, but the coke itself is usually found to give better results in the blast furnace, the decrease in coke consumption per ton of pig iron being in several cases quite marked. Fig. 3 shows coke of an excellent quality now being regularly made by the Koppers ovens of the Minnesota By-Product Coke Company from a mixture of Pittsburgh and Elkhorn coals, containing no low volatile coal whatsoever.

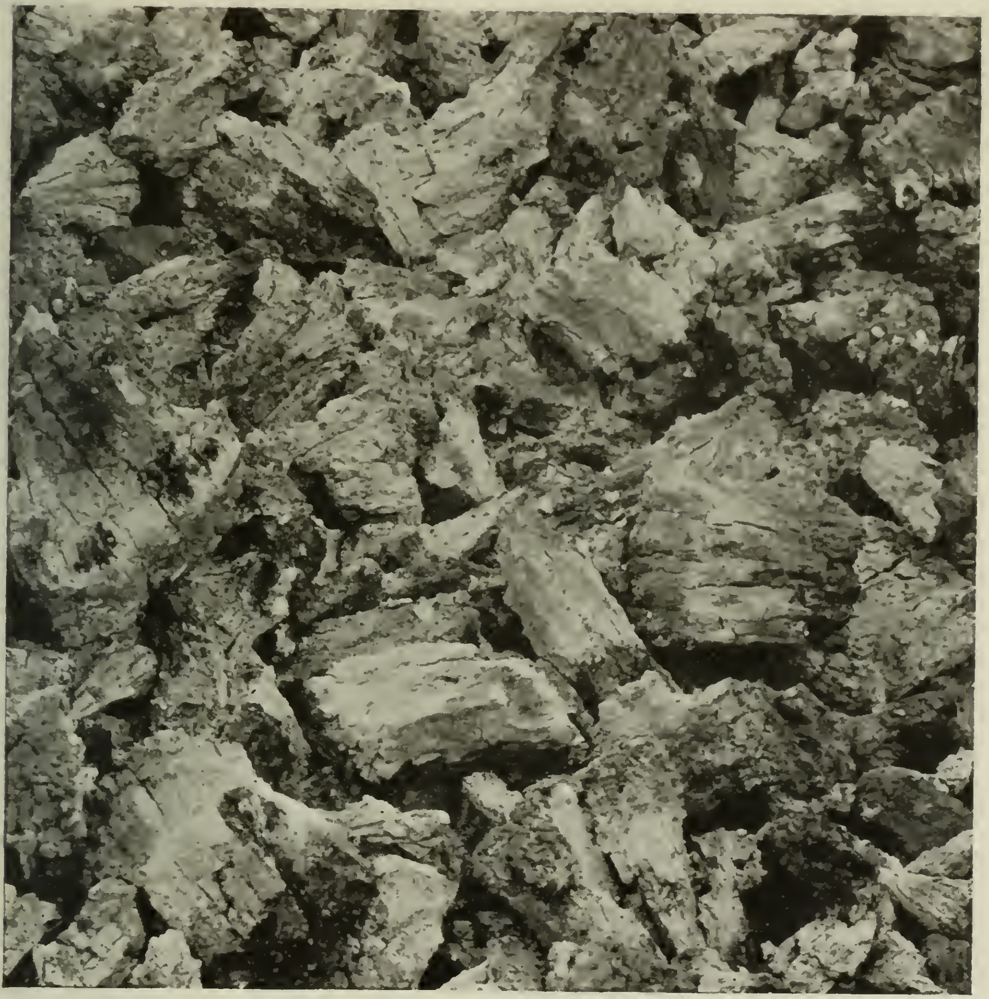
FIG. 11.



Coke from unmixed coal, Lower Kittanning seam, Preston County, W. Va.

Of the commonly used bituminous coals, the most important come from the Pittsburgh, Freeport, and Kittanning seams in Pennsylvania and West Virginia, and from two or three remarkable seams in eastern Kentucky, of which the Elkhorn is the most conspicuous. H. A. Kuhn[9] estimated that in 1912, 75 to 80 per cent. of all the iron production of the United States was located tributary to the coking coal of the Pittsburgh district, and, although this condition has to some extent been modified by the subsequent enormous development of the new Kentucky coal fields, it is probable that the Pittsburgh district still holds the

FIG. 12.



Coke from unmixed coal, Elkhorn seam, Pike County, Ky.

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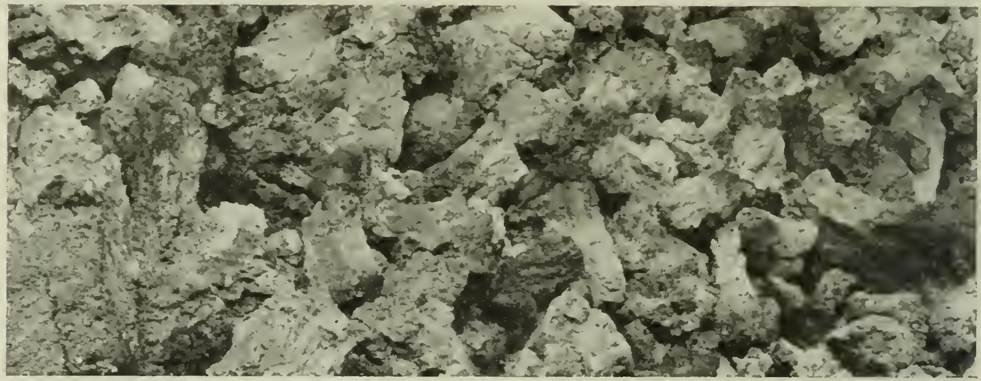
[9] *Trans. Am. Inst. Min. Eng.*, 1914, p. 640.

lead over any other as a source of by-product as well as of beehive coke.

The study of the behavior of various coals in the coking process, of the quality of the coke produced, of the nature and yield of the different by-products, and, finally, of the adaptation of oven design and operation to produce the maximum value in by-products consistent with the manufacture of good coke, is a real science, the importance of which can readily be recognized. A description of the large organization and equipment devoted by the H. Koppers Company to this special science would make an interesting chapter in itself. It is this science that has made possible, during the last ten years, the rapid and at the same time steady progress in oven construction, without the hap-hazard design and costly alterations of the previous decade. The engineering feat of building a battery of coke ovens out of several different kinds of refractory materials, of most complicated and varying coefficients of expansion, so adjusted and coördinated that, although the total longitudinal expansion of the battery when heated to operating temperatures is nearly four feet, every oven wall is straight and every flue is gas tight—such a feat is being repeated so many times that we are apt to lose sight of the high degree of skill involved. Something possibly more remarkable is the uniform and correctly proportioned heating to temperatures ranging considerably over 2000° F., by gaseous fuel, of more than 700 square feet of interior wall surface per oven—or, let us say, 50,000 square feet in a battery of seventy ovens. Yet even such

FIG. 13.

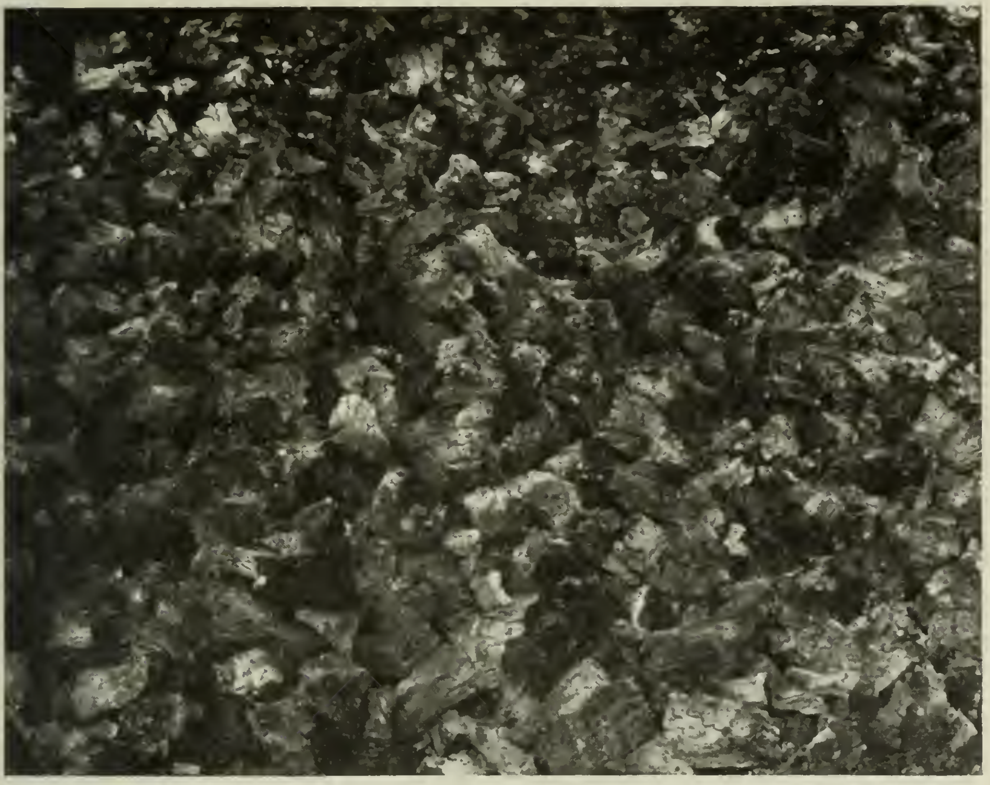


Coke from unmixed coal, Pulaski County, Ky.

accomplishments will often fail if we neglect the investigation of the coal which the ovens are expected to handle.

It is well known that the ordinary methods of laboratory investigation of coal—proximate and ultimate analysis, determination of calorific value, etc.—do not afford much assistance in obtaining information about the coking quality. From a general commercial standpoint some of them—*e.g.*, determination of ash, sulphur, and phosphorus, composition and fusing point of the ash—are indispensable. All of them have their place in adding to the sum-total of our knowledge of coal, and the writer believes that anything, no matter how remote its apparent application, that adds to that knowledge will, in the long run, aid in a more thorough understanding of the coking quality. As has been shown by the painstaking work of Doctor White, of the United States Geological Survey, a study of the amount and nature of combination of the oxygen is especially promising in this connection.

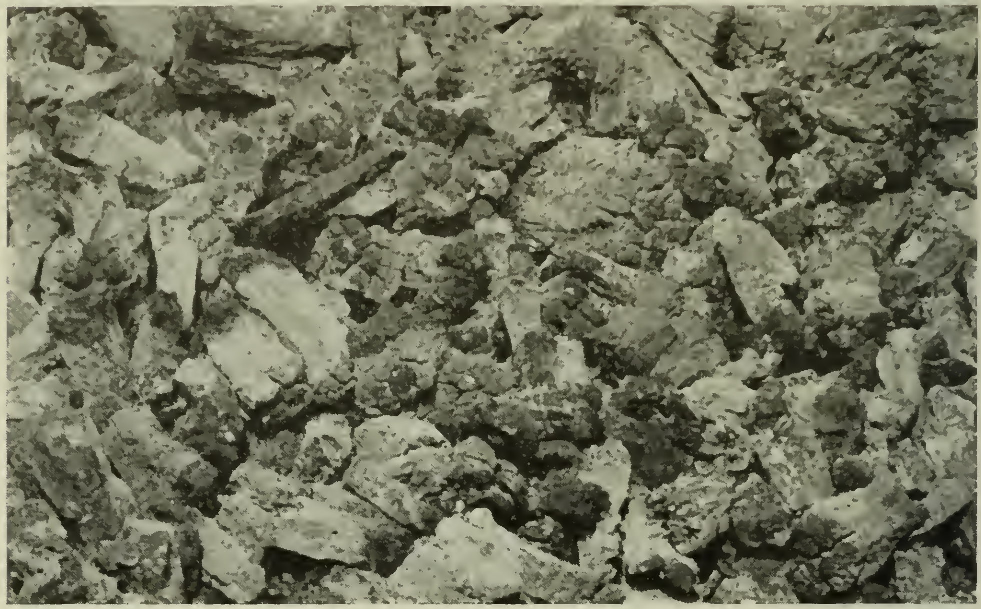
FIG. 14.



Coke from mixed washed coals, Pueblo County, Colo.

No practical substitute has yet been found for the actual distillation of the coal under conditions simulating those that occur when it is coked on a large scale. This is not so easy as it sounds, because the conditions are very complicated, and very insignificant modifications of them in the laboratory lead to the most erratic results. The idea is widely prevalent that ammonia, tar, benzene, toluene, naphthalene, cyanogen, etc., are *in* the coal, the same way that iron is present in hematite or calcium oxide in marble, and that all the chemist has to do is to "analyze" the coal, to find out the amounts of these substances it will produce when coked in a by-product oven. Such an idea is far from the truth. Coal contains merely the elements that under certain conditions of heating may go together to form these and other substances; but it no more contains these substances originally than an acre of uncultivated soil contains wheat or potatoes. The amount of variation possible in the yields of by-products under different conditions is quite analogous to the variation possible in crops per acre of soil, depending upon fertilization, temperature, rainfall, etc. Most published results of laboratory coal distillations are on this account almost valueless for comparison with by-product coke-oven practice.

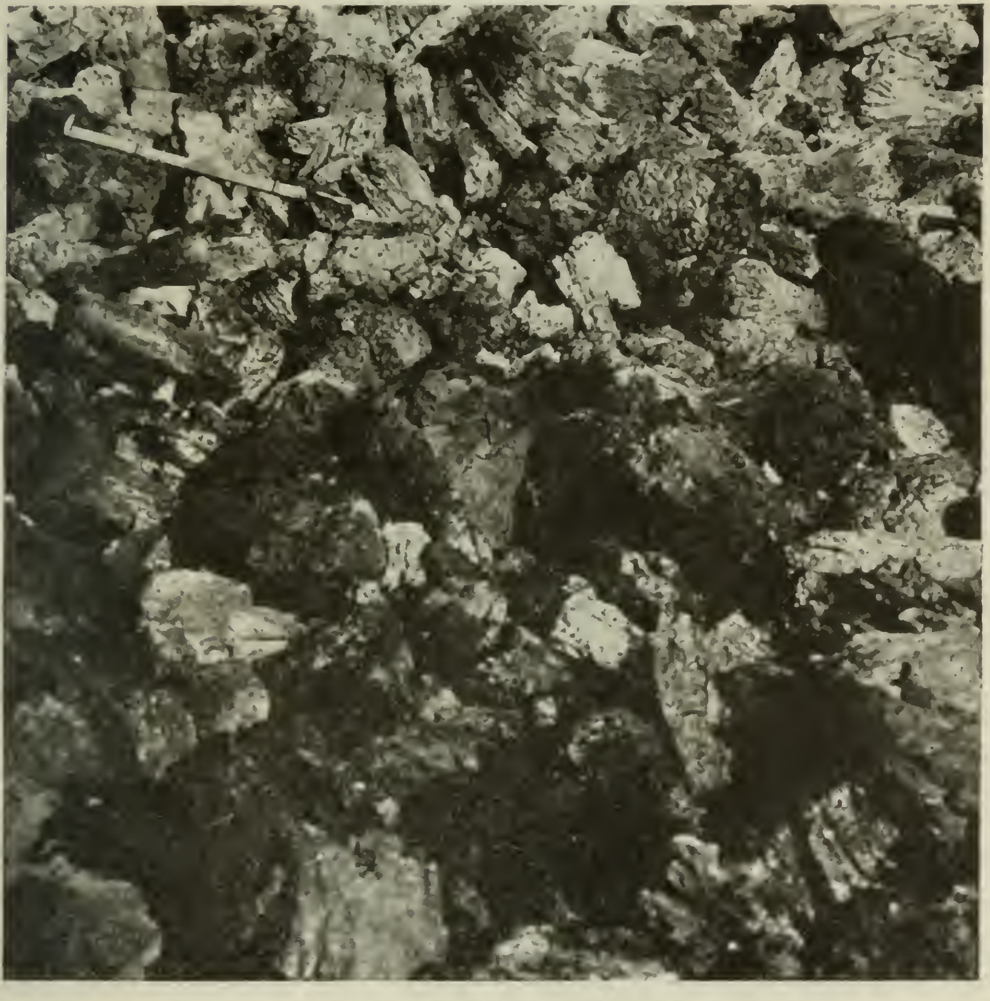
Fig. 15.



Coke from mixed washed coals, Pierce County, Wash.

The extraordinary possible variations of quality and yields of by-products might make laboratory investigation seem almost hopeless, were it not for the fact that in almost every case we can fix one fundamental rule: namely, *by-products both in quantity and quality, must be conditioned upon the production of a satisfactory coke.*

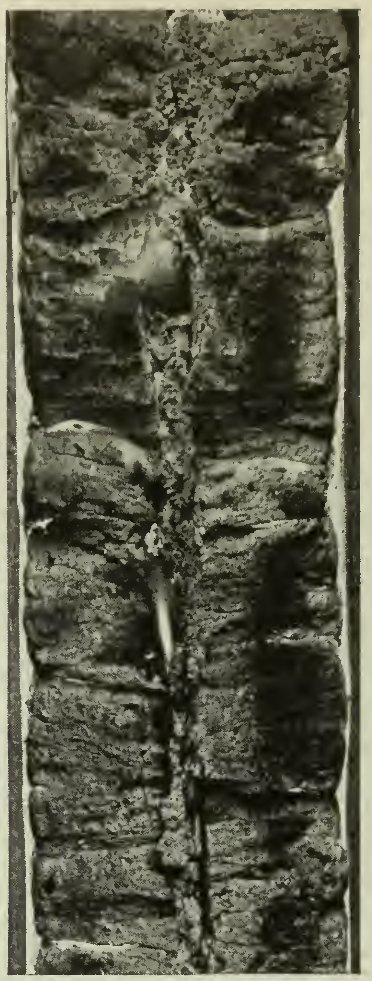
FIG. 16.



Coke from unmixed washed coal, Nova Scotia.

In our methods for testing every sample of coal proposed for use in a by-product coke oven, the conditions of distillation are adjusted according to this rule; and we are able in each case to predict to a reasonable degree of certainty the behavior and products of any coal in our type of oven. The yields of by-products can be determined very satisfactorily by this method in the laboratory, but any estimate of the quality of the coke must be checked by an oven test. The oven test is desirable, not only to ascertain the character of the coke made under ordinary operating conditions, but also to determine how these conditions must be varied

Fig. 17.

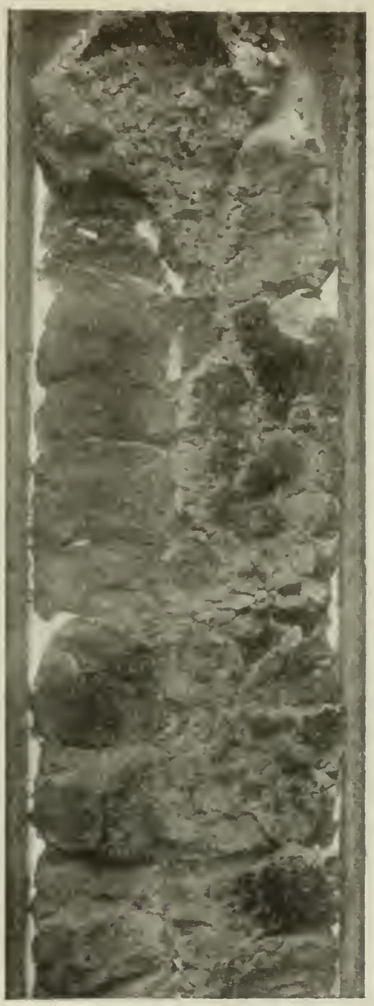


Coke from mixture of 85 per cent. Pittsburgh + 15 per cent. Pocahontas coals. Made slowly in wide oven. Thirty hours' coking time. Appearance in oven.

in order to produce the best possible coke from the coal in question. As has been pointed out in a previous article, the possibilities of making coke conform to a desired standard, by proper preparation, oven construction, coking regulation, and, as a last resort, mixture with some other coal, are remarkably great—much greater, in fact, than is generally supposed. The mistake of rejecting a coal for coke-making purposes on account of poor results obtained from a single test should be carefully avoided.

Some illustrations of cokes made from coals from a number of the best known American coal fields are given in Figs. 4 to 16. Figs. 5 and 6 are shown by courtesy of Mr. F. K. Ovitz, of the United States Bureau of Mines, who has written a very interesting bulletin on coke from Illinois coals.[10]

FIG. 18.



Coke from mixed coal: 85 per cent. Pittsburgh + 15 per cent. Pocahontas. Made rapidly in wide oven. Sixteen hours' coking time. Appearance in oven. Note sponge in upper part.

These illustrations are characteristic of the fingery or "pebbly" coke that is very likely to be produced from a coking coal of high oxygen type. As a rule, such coals require more careful adjustment and regulation of conditions in order to produce a satisfactory coke than is necessary in the case of the commonly used coals of Pennsylvania and West Virginia, which contain about the same percentage of volatile matter, but less oxygen. A typical block of coke made from coals of the Pittsburgh district is shown in Fig. 4.

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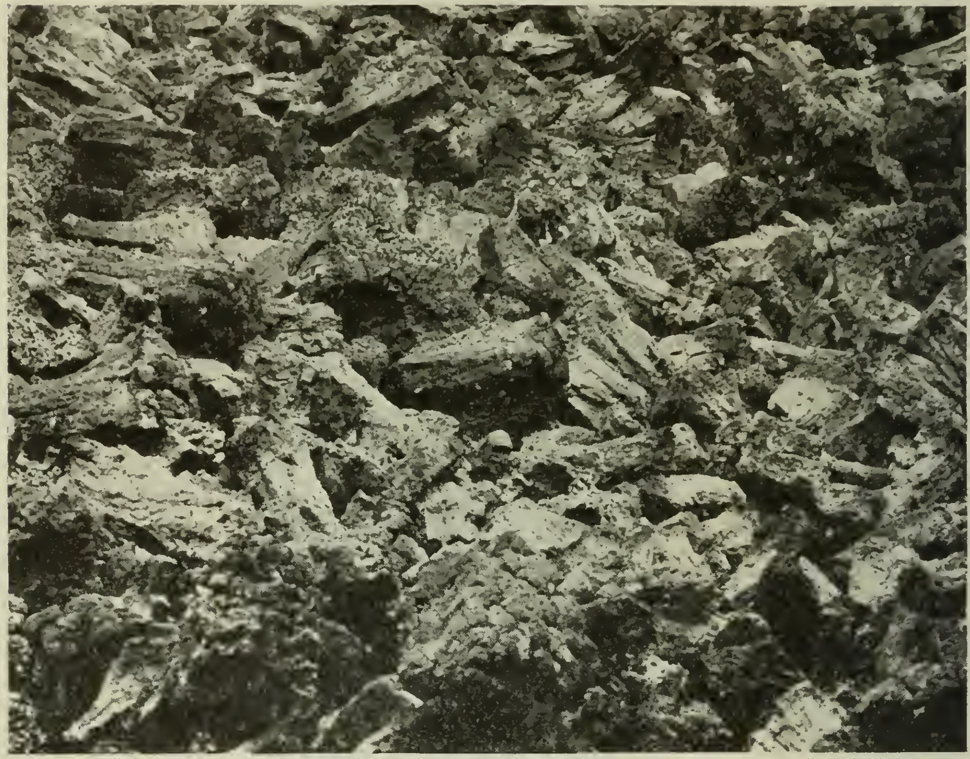
[10] U. S. Bureau of Mines, Bulletin 138.

The other pictures show the various cokes as they appear on the bench onto which the product of each oven is emptied from the quenching car. Fig. 16 is of some special interest because it shows an excellent coke made from a Nova Scotia coal which contains nearly 40 per cent. volatile matter. Each of these illustrations should be considered individually rather than as broadly typical, because the cokes were made at different plants and for different purposes, and were not intended for strict comparison. There is usually too much variation in the coking quality and by-product yields of coal from even a small district to admit of the presenta-

Fig. 19.

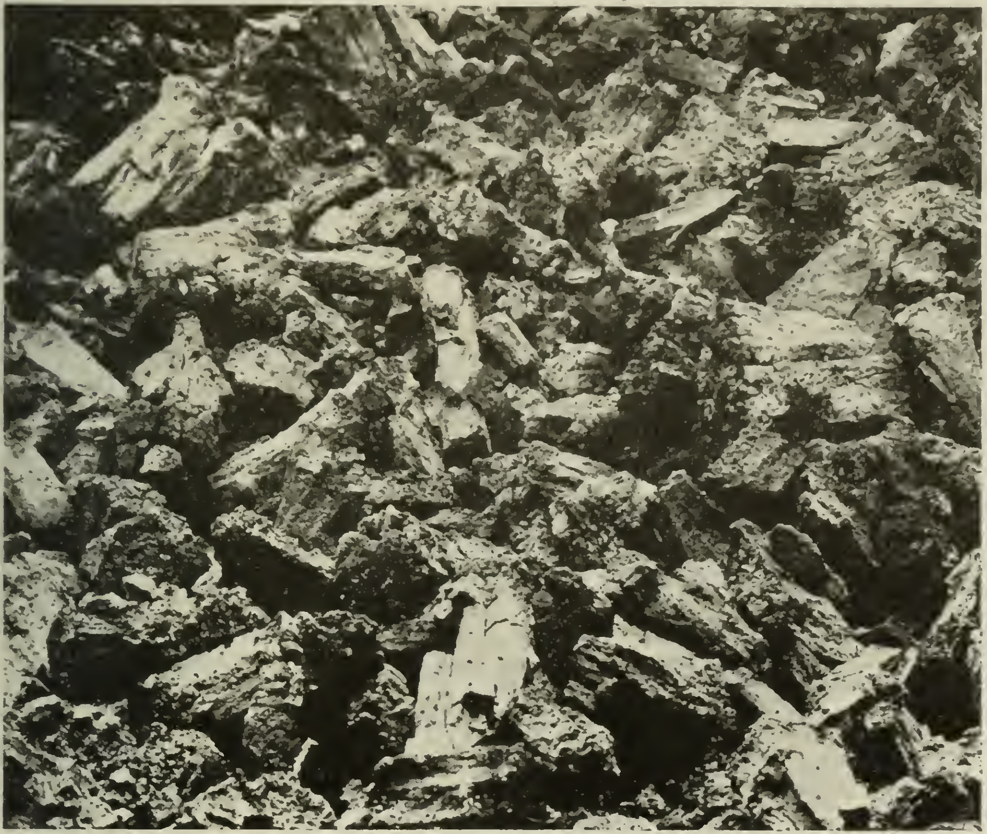


Coke from mixture of 85 per cent. Pittsburgh + 15 per cent. Pocahontas coals. Made slowly in wide oven. Thirty hours' coking time. Appearance on bench.

tion of "typical" samples or data, without the necessity of considerable latitude of judgment. There is sometimes as much variation from mine to mine on the same seam as from coal from two entirely different seams.

There is here a very interesting and virtually unexplored field, namely, the correlation of the geological relations of coals with their coking qualities. There is no doubt that this subject is of great practical importance. A thorough knowledge of it would, for instance, enable us to estimate from simple geological considerations the value of a new mine on a known seam for by-product coking; or, on the other hand, would assist in defining an unknown seam in new territory from the results of laboratory coking tests. Our present knowledge, however, is much too meagre for this. There are a few outstanding facts which will be discussed briefly.

FIG. 20.



Coke from mixed coal: 85 per cent. Pittsburgh + 15 per cent. Pocahontas. Made rapidly in wide oven. Sixteen hours' coking time. Appearance on bench.

The geological age of a coal is no criterion as to its coking quality. As good by-product yields and as good coke are obtained from the comparatively recent coals of Colorado as from the early carboniferous strata of Pennsylvania. The coking properties of the Lower Kittanning seam undergo most remarkable changes parallel with the extent of devolatilization southeastward from Allegheny and Fayette counties, Pennsylvania, to the Potomac basin in Maryland. The phenomena of prime importance seem to be those of deoxidation rather than of devolatilization. The highly oxygenated coals of Illinois may have less volatile matter than coal from a portion of the Pittsburgh seam and yet produce a much inferior coke. In fact, the best basis we have for differentiation, with respect to coking quality, seems to have close relation to high or low oxygen content. We might make the above comparisons of these two kinds of coal with approximately the same percentage of volatile matter.

	Low-oxygen coking coals	High-oxygen coking coals
Examples	Appalachian bituminous coal fields	Illinois, Indiana, Washington
Shape	Blocky	Slender, tapered, fingery.
Hardness	Hard	Soft.
Exterior surfaces	Even	Sometimes smooth; but often having transverse seams or sometimes even masses of pebbly carbon.
Cell-structure	Regular—usually rather heavy cell walls.	Irregular—thin cell walls.
By-products: Gas	High yield—rich—little CO or CO_2.	Low yield—lean—much CO and CO_2.
Tar	High yield—thicker—high specific gravity—less tar acids.	Low yield—thin—lower specific gravity—more tar acids.
Ammonia	Normal	Often higher.
Benzol	Normal	Irregular.
Combined water	Low	High.
Rate of coking	Normal	Slow.
	The excess of fusible bituminous matter accumulates in the upper centre of the oven, forming a wedge-shaped, honeycombed mass, called "sponge."	Any excess of fusible bituminous material forms pebbly masses more or less loosely agglomerated and not always confined to the centre of the oven.

It would be very interesting to compare the results of normal geological deoxidation, such as has occurred in parallel undisturbed strata, like the Freeport, Kittanning, and Pittsburgh seams in Allegheny County, Pennsylvania, with what one might term "accelerated deoxidation," such as has occurred from the western to the eastern portions of the Lower Kittanning seam. Additional data must, however, be accumulated before we can begin to generalize on this subject.

The famous Pittsburgh seam is the most regular and dependable of any with which we have to deal. Even in this seam, however, the percentage of volatile matter drops gradually from about 37 per cent. in the western portion to about 27 per cent. in portions of the Connellsville basin. Attention has heretofore been given principally to this phenomenon of devolatilization, and it would be interesting to study the variation in coking quality from the standpoint of deoxidation. Here the differences in oxygen content are relatively smaller, and, in spite of the considerable range of volatile matter, we actually find comparatively small differences in the coking quality of different parts of the seam.

Figs. 17 and 18 show coke made from Pittsburgh coal + 15 per cent. Pocahontas in ovens of 20 inches average width, coked 17 hours and 30 hours respectively, heats having been adjusted to the coking time. Figs. 19 and 20 show the cokes from these ovens on the bench. Please note the difference in the amount of sponge, which is quite characteristic. The 17-hour coke, although it is smaller sized and more cross fractured, is stated to give excellent results in the blast furnace. In ovens somewhat narrower, such as those at St. Paul, and with a coking time of 19 hours, the Pittsburgh coal gives very little sponge.

The Elkhorn coal, the development of which in the last few years has been one of the prominent events in the coal industry, appears to occupy a position midway between the eastern high volatile coals and the more highly oxygenated coals of Illinois and Indiana. Its low ash and sulphur content and high by-product yields place it in the first rank of our best coking coals. It makes no sponge; but the coke shows some pebbly carbon like that characteristic of Illinois coals.

The data (Table V) showing the elimination of sulphur in coking various coals in by-product ovens are of considerable practical importance. The figures for Alabama coals and for mixtures of Pennsylvania with West Virginia, and Pennsylvania with Kentucky coals are each averaged from a large number of tests;

the other figures are from individual tests. Please note the high percentage expelled in coking Pittsburgh coal and the lower percentage from the higher oxygen coals of Washington and Kentucky. J. R. Campbell[11] has observed the higher percentage of sulphur elimination in the by-product oven, and states that in beehive practice they figure on about 20 per cent. elimination.

Sulphur Elimination in Coking Coals in Koppers Ovens.

State	County	Seam	Coking time hrs.	Coke yield per cent.	Sulphur			
					Per cent. in coal	Per cent. in coke	Per cent. of total eliminated	Per cent. of total retained
Colorado	Pueblo and Gunnison	....	21.5	74.0	0.68	0.57	38.0	62.0
Colorado	Pueblo and Gunnison	....	19.0	74.0	0.58	0.52	34.0	66.0
Colorado	Pueblo and Gunnison	....	19.5	73.0	0.51	0.47	32.7	67.3
Colorado	Pueblo and Gunnison	....	20.0	75.5	0.58	0.53	31.4	68.6
Colorado	Pueblo and Gunnison	....	18.0	73.0	0.58	0.54	32.0	68.0
Colorado	Pueblo and Gunnison	....	19.5	74.0	0.63	0.40	53.0	47.0
Alabama	Jefferson	....	18.0	75.0	0.99	0.84	36.4	63.6
Alabama	Jefferson	....	18.0	75.0	1.07	0.92	35.5	64.5
Alabama	Jefferson	....	18.0	75.0	0.99	0.99	25.0	75.0
Alabama	Jefferson	....	17.0	75.0	0.79	0.64	32.3	60.7
Alabama	Jefferson	....	18.0	75.0	1.39	1.17	36.8	63.2
Alabama	Jefferson	....	18.0	75.0	1.17	1.06	32.0	68.0
Alabama	Jefferson	....	18.0	71.0	1.25	1.23	30.2	69.8
Pennsylvania	Allegheny	Pittsburgh	20.0	70.0	1.12	0.84	47.5	52.5
Pennsylvania	Fayette	Pittsburgh (Klondike)	17.0	68.0	1.03	0.95	37.3	62.7
Pennsylvania	Fayette	Pittsburgh (Klondike)	19.0	68.0	1.03	1.00	34.0	66.0
Pennsylvania	Westmoreland	Pittsburgh	19.5	71.0	1.85	1.50	42.4	57.6
Pennsylvania	Washington	Pittsburgh	20.0	72.0	1.06	0.76	48.3	51.7
Pennsylvania	Fayette	Lower Kittanning	19.0	75.0	0.87	0.75	35.3	64.7
Washington	Pierce	No. 6	17.5	70.0	0.60	0.58	32.2	67.8
Washington	Pierce	Mostly No. 6	19.0	70.0	0.53	0.46	39.3	60.7
Washington	Pierce	No. 7	19.0	76.0	1.70	1.57	29.8	70.2
Washington	Pierce	No. 8	19.0	72.0	0.46	0.49	35.8	64.2
Washington	Pierce	No. 8	17.5	72.0	0.54	0.51	32.0	68.0
West Virginia	Preston	Lower Kittanning	17.5	70.0	1.84	1.56	40.6	59.4
West Virginia	Marion	Pittsburgh	16.5	68.0	1.48	1.56	28.3	71.7
West Virginia	Marion	Pittsburgh	16.5	68.0	1.62	1.63	31.6	68.4

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[11] *Trans. Am. Institute Min. Eng.*, 1916, liv, p. 181.

Sulphur Elimination in Coking Coals in Koppers Ovens.—Continued.

State	Mixtures with Pocahontas Coal	Coking time, hrs.	Coke yield, per cent.	Sulphur			
				Per cent. in coal	Per cent. in coke	Per cent. of total eliminated	Per cent of total retained
Illinois	20 per cent. Illinois+80 per cent. Pocahontas	18.0	84.0	0.87	0.75	27.7	72.3
Pennsylvania	85 per cent. Pittsburgh (Allegheny Co.)	20.0	71.0	0.90	0.72	43.3	59.7
Pennsylvania	60 per cent. Pittsburgh (Allegheny Co.)	20.0	75.0	0.77	0.67	34.8	65.2
Pennsylvania	60 per cent. Pittsburgh (Allegheny Co.)	22.0	78.0	1.05	0.96	28.7	71.3
Pennsylvania	85 per cent. Pittsburgh (Fayette Co.)	21.0	71.0	1.07	0.81	46.4	53.6
Pennsylvania	70 per cent. Pittsburgh (Fayette Co.)	20.0	73.0	1.05	0.79	45.1	54.9
Pennsylvania	60 per cent. Pittsburgh (Fayette Co.)	20.0	73.0	1.03	0.76	46.2	53.8
Pennsylvania	20 per cent. Pittsburgh (Fayette Co.)	18.0	84.0	0.79	0.69	46.7	73.3
Kentucky	75 per cent. Pond Creek	20.0	75.0	0.55	0.49	33.2	66.8
Kentucky	75 per cent. Pond Creek	22.0	76.0	0.64	0.67	20.4	79.6
Kentucky	30 per cent. Elkhorn	20.0	80.0	0.69	0.68	21.2	78.8
Kentucky	75 per cent. Pond Creek	20.0	75.0	0.52	0.48	30.9	69.1

Projection Method of Testing Screw Threads. F. D. JONES. (*Machinery,* vol. 24, No. 8, p. 735, April, 1918.)—Considerable progress has been made in the development of apparatus for detecting inaccuracies in screw threads, especially during the past three years, because of the tremendous amount of screw cutting necessary in connection with munitions manufacture and the great importance of maintaining the screw-thread dimensions within the limits prescribed. Different types of gauges and precision measuring machines have been improved in design and new forms of apparatus originated. A modern and very effective method of testing screw threads is by the use of an optical projection apparatus. The principle is very simple: An image of the thread is projected upon a suitable screen and is then compared with the profile or outline of an accurate thread of standard proportions. It is necessary, of course, to determine previously the magnification or the extent to which the thread under observation is to be enlarged upon the screen, so that the profile or thread outline used as a standard in making comparisons may be drawn to a corresponding scale. This projection method shows errors in the pitch, angle, or form of the thread, and it is especially valuable for testing the shape of a

Whitworth thread. In order to secure a permanent record of the thread outline, the edge of the shadow projected on the screen may be traced in pencil upon a sheet which is filed for future reference. These outlines are sometimes sent to gauge-makers to show them the exact nature of the error, or to manufacturers when the outline is of a thread on the product instead of a gauge thread.

A photograph of the outline of a projected thread may be obtained without much difficulty instead of tracing the contour in pencil, although the latter method is simpler, more rapid, and less expensive. One method of securing a photograph is as follows: A part similar in form to the focusing bellows of camera is attached in front of the projector lens and is arranged to hold a plate slide. The exposure is made either on a rapid plate or directly upon bromide paper. A ground-glass screen is inserted in the plate slide prior to making the exposure, and is used for focusing. For comparative purposes the outline of a standard thread form may be secured in conjunction with the photograph of the thread to be examined by first making an artificial negative. This should be a duplicate of the standard thread, except that the outline is enlarged in proportion to the magnification of the projected thread image. A magnification of 20 is considered about right for making photographic reproductions. The artificial negative may be made by drawing as accurately as possible the thread contour on tracing paper. This outline, which should be twenty times the actual size of the thread, is next filled in with India ink to obtain a solid black thread section. Several coats of the ink should be applied, and, to prevent the paper from wrinkling and buckling, it should be moistened before applying the ink and then be smoothed out thoroughly after the ink is dry by using a hot flat-iron. This artificial negative is placed in contact with the sensitized plate preparatory to making the exposure, and it serves as a standard for comparing the photographic reproduction with the actual thread. The artificial negative must be set so that it will be parallel and close enough to the projected image to enable the actual and true outlines to be compared readily. The optical projection apparatus is not restricted in its use to testing screw threads, but may be employed to correct the accuracy of the profiles of gear teeth, the shapes of cams or gauges of the contour type, or any other parts having an outline that may be projected and compared with a standard form.

SOIL ALDEHYDES.*

A SCIENTIFIC STUDY OF A NEW CLASS OF SOIL CONSTITUENTS UNFAVORABLE TO CROPS, THEIR OCCURRENCE, PROPERTIES AND ELIMINATION IN PRACTICAL AGRICULTURE.[1]

BY

JOSHUA J. SKINNER, Ph.D.

INTRODUCTION.

THE isolation and identification of definite organic compounds from soils has stimulated investigations pertaining to the physiological effect of various organic compounds on plants. The chemical composition of the organic matter of soils concerns every investigator of soil problems: it may be the physicist, the chemist, the bacteriologist, the physiologist, or the agronomist. The quantity of organic matter in the average soil is considerable. The average content in the soils of the United States is 2.06 per cent., and of the subsoils, 0.83 per cent. (11).[2] The organic compounds which have been found to occur in soil organic matter affect plants differently: some are beneficial to plant life, others are inimical to proper plant development, and still others have no effect on growth. In every soil there exists a balance of these two contesting influences, the good and the bad. The decreased soil fertility, in so far as it is due to the chemical composition of its organic matter, as a single factor, is due to the preponderance of that type of biochemical action which will result in the accumulation of harmful compounds; increase in soil productivity, on the other hand, is due to favorable biochemical action resulting in the accumulation of compounds beneficial to plants. Whether one or the other predominates is due to soil conditions, drainage, composition, plant occupation, etc., which can be influenced by soil management, such as tillage, cultivation, drainage, liming, fertilization, and by crop rotation, all of which influence the biochemical factors in soils and, through them, soil fertility.

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* Communicated by Dr. Oswald Schreiner.

[1] Contribution from the Laboratory of Soil Fertility Investigations.

[2] Refers to literature citation in Bibliography appended.

During the last ten years a large number of organic compounds have been isolated from soils by Schreiner and his co-workers, Shorey, Walters, Lathrop, and Wise, of the Laboratory of Soil Fertility Investigations. Previous to that time the constituents of the organic matter of soils were practically unknown. The individual compounds isolated are agroceric acid (46), agrosterol (46), arginine (49), acrylic acid (61), adenine (61), benzoic acid (62), α-crotonic acid (82), creatinine (60), cyanuric acid (85), choline (61), cytosine (49), dihydroxystearic acid (46, 48), glycerides (49), guanine (42), hentriacontane (49), histidine (49), hypoxanthine (49), lignoceric acid (49), lysine (61), monohydroxystearic acid (49), metahydroxytoluic acid (62), mannite (61), nucleic acid (61), paraffinic acid (49), peptones (81), proteoses (81), pentosan (49), pentose (49), phytosterol (49), picoline carboxylic acid (47, 48), oxalic acid (61), rhamnose (61), resin (49), resin acids (49), resin esters (49), saccharic acid (61), salicylic aldehyde (61), succinic acid (61), sulphur (61), trimethylamine (61), tetracarbonimid (63), trithiobenzaldehyde (61), vanillin (62), and xanthine (49).

From this list it is seen that the compounds represent a great variety of chemical classes: there are paraffinic hydrocarbons, hydroxy fatty acids, and other organic acids, organic bases, esters, alcohols, aldehydes, carbohydrates, hexone bases, pyrimidine derivatives, purine bases, pyridine derivatives, organic sulphur compounds, organic phosphorous compounds, and nitrogenous compounds.

Especially interesting, in passing, are the groups of nitrogenous compounds. Some of these are beneficial and others harmful to plant growth; they are absorbed by plants as such, enter into the cell, and react with the protoplasm, causing effects either beneficial or detrimental, as the case may be. Among the beneficial compounds of this class which have been found in soils are creatinine (64, 65), creatine (64, 65, 10), hypoxanthine (54, 56), xanthine (54, 56), nucleic acid (54, 56), guanine (54, 10), histidine (54, 66), arginine, (54, 66), and choline (54). Other nitrogenous compounds reported as beneficial are acetamide (25), alanine (54, 25, 24, 31, 10), allantoin (54, 31), amygdaline (31), asparagine (54, 31, 24, 10), betaine (30), formamide (25), glycocoll (54, 25, 24, 31), and leucine (54, 31).

Not all nitrogenous compounds are beneficial, as is shown by the following presentation: Guanidine (54, 55, 10), a nitrogen-containing body, is very harmful to plants. It is especially interesting in that it produces effects similar to those produced by plant diseases, manifesting itself by bleached spots on the leaves, which spread, cause wilting and final collapse. The effect is accentuated by nitrate, and is less observable in the total absence of nitrate. The striking difference between effects of the two closely related nitrogenous compounds, glycocoll and methyl glycocoll (54, 57), is also interesting. Glycocoll ($CH_2.NH_2.COOH$) is amido-acetic acid, and is one of the simpler degradation products found where decomposition is occurring. It exists in the tissue and seed of many plants. Methyl glycocoll ($CH_2.NH.CH_3COOH$) differs in its chemical structure from glycocoll, not only in that it contains the methyl group, CH_3, but also in that the amido group, NH_2, is thereby changed to an imido group, NH. It is not a simple protein body. Glycocoll is beneficial and is utilized as a source of nitrogen, while methyl glycocoll is also absorbed, but causes decreased growth and a peculiar twisted lateral growth of the leaf of the plant. Among other nitrogenous compounds which have been reported as harmful are aniline (30), aspartic acid (31, 43), atropine (30), barbituric acid (25), caffeine (30), carbamic acid (25), cocaine (30), diphenylamine (30), hexamethylene tetramine (25), hippuric acid (25, 31), morphine (30), myronic acid (31), naphthylamine (30), neurine (43), piperidine (43), pyridine (43), quinine (30), skatol (43), solanine (54), tetranitromethane, (25), theobromine (31), tyrosine (43), para urezine (25, 31), and uvitonic acid (48). Quinoline and pyridine (21) have recently been found by Funchess to be very beneficial to growth in soil culture, but this beneficial action is probably due to products of decomposition of the nitrogenous compounds, and not to the compound itself.[3]

Among other compounds which have interesting characteristic and contrasting effects on plants are cumarin, quinone, and vanillin (52, 53). Cumarin decreases growth and causes a shorter and broader leaf than is normal for wheat, and only the first leaves are usually unfolded, the other leaves remaining wholly or partially within the swollen sheath. The leaves that break forth are distorted, curled, and twisted. This characteristic development is not noticeable when the plants are grown in cultures containing considerable amounts of phosphates. The effect of quinone is decidedly different: it produces long, thin leaves and tall, slender plants. Potash ameliorates this effect to a large extent. Vanillin also produces thin, slender plants, but affects the roots more than the tops. It is interesting that the effects of vanillin are partially overcome by nitrate fertilizers.

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[3] Since the preparation of this manuscript Funchess has shown that quinoline and pyridine nitrify in soils, quinoline nitrifying the more rapidly the more acid the soil. The nitrification of nitrogenous compounds was inhibited by aldehydes. (Funchess, M. J., "The Nitrification of Pyridine, Quinoline, Guanidine Carbonate, etc., in Soils," Alabama Exp. Sta., Tech. Bull. No. 3, Bull. No. 196, June, 1917.)

In this paper the chief interest centres in the occurrence properties, and elimination of that class of soil constituents which partake of the nature of aldehydes. The results obtained in laboratory greenhouse and field with certain of these compounds will be presented, following a general discussion of the subject.

GENERAL DISCUSSION OF THE EFFECTS OF ORGANIC COMPOUNDS IN SOILS, ESPECIALLY SOIL ALDEHYDES.

Compounds, or a mixture of compounds, having the properties of aldehydes have been found in many soils, but only three—salicylic aldehyde, vanillin, and trithiobenzaldehyde—have been definitely identified thus far, and this paper concerns itself principally with the effect of this class of compounds on plant life and their influence on soil fertility.

Salicylic aldehyde was first found in garden soils from the Mount Vernon estate, Virginia (61), and later was found in a number of other soils from widely different sections.

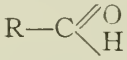
Materials having the odor of vanillin have been separated from a number of soils, but it was first separated in sufficient amount to identify from a Florida soil (62); it has been encountered quite frequently since in soils from other parts of the United States.

Trithiobenzaldehyde (61) was found first in a soil from California, but has not been encountered frequently.

It will be shown later that aldehydes are common in many soils, and especially in soils of low productivity. Alcohols and acids, the reduction and oxidation products of aldehydes,

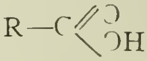
$R{-}O{-}H$

Alcohols



$R{-}C\begin{smallmatrix}{\diagup\!\!\!\diagup} O \\ \diagdown H\end{smallmatrix}$

Aldehydes



$R{-}C\begin{smallmatrix}{\diagup\!\!\!\diagup} O \\ \diagdown OH\end{smallmatrix}$

Acids

have been encountered in soils, which makes the study of the action of aldehydes on plants essential.

A review of the investigations on the action of aldehydes and other soil organic compounds on growth will be given here.

The earlier studies of the effect of soil organic compounds on growth was made in water-culture solutions. In the case of most of the compounds it was difficult to get sufficient quantities of the material to make exhaustive investigations of its effect on growth in soils. The absorptive power of some soils, together with their biological activities, affects added organic materials to such an extent that results are uncertain unless accompanied by tests to show the changes that the added substance may undergo. With water-culture experiments this difficulty is in part obviated. The experiments are made under better controlled conditions, and fewer factors enter into the results. While one should not draw definite conclusions from water-culture experiments as to what might take place under field conditions, yet it is impossible to study factors singly in the field, as must be done in scientific experimentation. The results secured in water cultures in this investigation have proved of vast importance; it would have been impossible to have shown that some of the nitrogenous compounds were used as such in plant metabolism without the use of water cultures. The field studies which are presented later are an outgrowth of the laboratory studies with water cultures.

Some recent investigators have objected to the use of water cultures in work of this kind, and have made experiments which should and do show that organic compounds having harmful properties do not exert as harmful an effect in soil cultures as in water cultures. They decry the use of such methods in soil and plant physiological investigations. It would be just as proper for the chemist to decry the use of C.P. reagents or the bacteriologist to disavow pure cultures as for the plant physiologist to decry the use of water cultures.

The first soil organic compound isolated, picoline carboxylic acid, did not prove to be harmful to plants except in high concentration (47, 48). Below 100 parts per million in distilled water it was slightly stimulating to wheat seedlings. Dihydroxystearic acid (46, 48), which has been found in soils, was very harmful to wheat in distilled water: in as low a concentration as 20 parts per million growth was materially reduced, and with 200 parts per million the seedlings were severely injured. In nutrient solutions (50), composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, the dihydroxystearic acid in concentrations of 50 parts per million also proved to be harmful. It was less harmful in the solutions composed principally of nitrate, showing that nitrate had an influence in changing its physiological effects.

Schreiner and Skinner have shown that a group of nitrogenous soil organic compounds are beneficial to growth and are absorbed and utilized by the plant as a source of nitrogen. Among these are creatinine and creatine (64, 65), nucleic acid (54, 56), hypoxanthine and xanthine (54, 56), guanine (54, 10), histidine and arginine (54, 56), and choline (54).

An extensive study of the soil aldehydes has been made and reported by Schreiner and Skinner. Salicylic aldehyde and vanillin (58, 67, 68) were first shown to be harmful to a number of plants in distilled water, in nutrient solutions, in some soils in pots, and in the field. Salicylic aldehyde affected growth much more than did vanillin. In the investigation with soils in pots it was found that the aldehydes were harmful in some soils and not in others. The soils in which these compounds showed no detrimental effect on plant development are good productive soils, with strong oxidation powers, and have good bacterial activity. The salicylic aldehyde was applied usually in amounts of 150 pounds per acre, and the vanillin 300 pounds per acre. It was further indicated that the aldehydes were not so harmful in limed soils, and that fertilizers had an action in ameliorating their harmfulness.

Experiments were made on three different soils in the field (70), each soil differing chemically, biologically, and physically, differing as to their crop-producing powers, and differing in that each was of a different origin and different geographical location. The salicylic aldehyde and vanillin were harmful in two of these soils, and had practically no effect in the third. On the Susquehanna silty clay loam, an unproductive soil on the Arlington Experimental Farm, Virginia, both aldehydes reduced the production of cow peas, garden peas, and string beans (58, 68). These soils were analyzed to determine whether or not the aldehydes remained in the soil as such throughout the growing period. The compounds were found in this soil six months after their application; that is, at the end of the crop season. It was further shown that lime overcame the harmful effects of both aldehyde compounds, and that on this soil fertilized with phosphate the bad effects of salicylic aldehyde were greatly reduced, and on soil fertilized with sodium nitrate the effects of vanillin were lessened. The aldehydes did not persist in the fertilized soil. That aldehydes are harmful in some soils and not in others is probably accounted for by their inability to persist in soils having strong oxidizing powers and good biological activities. This is further demonstrated by the field experiments of Skinner and Noll (70) on the strong productive Hagerstown loam. On this soil the aldehydes were not harmful, and by chemical methods it was shown that the added substances were changed or destroyed in the soil.

Fraps (20) made some pot experiments with several soil organic compounds. He studied the effects of dihydroxystearic acid in soils. He states the material he used was impure dihydroxystearic acid. In an experiment growing corn (soil No. 1600) untreated pots produced 9.3 grammes and 10.1 grammes dry weight, while the pots to which dihydroxystearic acid in amounts of 500 parts per million were added produced 8.8 grammes dry matter, a reduction of 10 per cent. When calcium carbonate was added with the dihydroxystearic acid growth was reduced 42 per cent. The two untreated pots growing sorghum were very uniform. One produced 20.9 grammes dry matter and the other only 13.5 grammes, which makes a comparison of the treated pots rather uncertain. The dihydroxystearic acid treated pot produced 19.0 grammes dry matter, and the dihydroxystearic acid plus lime 19.9 grammes. It is rather unfortunate that a culture with lime alone was not included in this test; as it is, no comparison can be made.

In another soil (No. 1956) which had been fertilized with phosphate, nitrate, and potash, dihydroxystearic acid at the rate of 500 parts per million reduced the growth of corn from 18.0 grammes to 15.1 grammes of dry material, a reduction of 16 per cent. Dihydroxystearic acid with lime was still more harmful. In the experiment growing sorghum the average dry weight of two pots of the fertilized soil was 12.7 grammes, and that of the two pots with dihydroxystearic acid 10.5 grammes, a reduction of 18 per cent. Again, the dihydroxystearic acid with calcium carbonate was more harmful, but no checks are included with the soil untreated or with lime alone.

The pot experiments with the aldehyde vanillin are also interesting and valuable in that he studied the persistence of the aldehyde in the different soils used in the experiment. In the experiments, adding vanillin in amount of 100 parts per million before planting, it was harmful in two soils out of nine used. When used at the rate of 200 parts per million it was harmful in each case. In other experiments the vanillin was supplied in fractional parts to the soil during the growth of the plant. In virtually all cases the growth of the plant was injured, except in the lower concentrations of 100 parts per million. Periodical application of this concentration injured the plants but did not kill them in the case of these Texas soils, in which vanillin disappeared rapidly. An examination of the results shows that the more rapid and complete the loss of vanillin in the soil the less is the injury observed in the growing plant. Thus his soil No. 3346 with vanillin showed a decrease in plant growth of 27 per cent. and a loss in vanillin in two weeks' time of only 24 per cent.; soil No. 4747 with vanillin showed a decrease in plant growth of about 14 per cent. and a loss of vanillin in two weeks' time of 60 per cent.; soil No. 4605 with vanillin showed a decrease of only 6 per cent. in growth but a loss of 71 per cent. in vanillin in two weeks' time.

Fraps's experiment with the effect of vanillin on three soils (Nos. 5101, 5649, and 1579) which had been fertilized with acid phosphate plus ammonium nitrate showed that the vanillin was extremely harmful to sorghum in each of these soils with the fertilizers applied. One hundred parts per million was injurious in two of these soils. Where 200 parts per million were added it killed the plants in one case and severely injured growth in the other two cases. Where 1000 parts per million were applied with the fertilizers, the plants were killed in every case. In another experiment in which he used seven soils, vanillin at the rate of 200 parts per million without and with acid phosphate and ammonium nitrate produced very injurious effects on the plants grown. In the experimental work of the present investigation, as will be shown later in this paper, acid phosphate did not overcome the bad effects of vanillin. No additional injurious action has been observed, however, when applied with this fertilizer. In the field experiments and with the soil in pots the harmfulness of vanillin was lessened by sodium nitrate; nitrogen in the form of ammonium nitrate or in other forms was not used. Fraps's work seems to show that ammonium nitrate makes the vanillin even more harmful, indicating that some biological action takes place which produces conditions very bad for plant growth.

Fraps points out the well-known fact that these organic compounds are not as harmful in soils as in water culture, but seems to lose sight of the important results which his work so well demonstrates; that is, that these compounds act differently in different soils and under different conditions, and that they act differently because when formed or added they will remain in some soils and under some conditions, while they are destroyed in other soils.

Upson and Powell (76), working with a black silt loam of excellent texture and rich in organic matter, found that vanillin in amounts varying from 250 to 1000 parts per million had no effect on the growth of wheat plants in pots, but with another soil of equally good texture but less productive vanillin depressed growth slightly. Salicylic aldehyde in the same soil was somewhat more harmful, but it did not depress growth below 15 per cent. in any case. They conclude that aeration and absorption are important factors in overcoming the effects of the aldehydes, but give no experimental evidence. They made no attempt to ascertain whether vanillin or salicylic aldehyde existed in their soil for any length of time or whether it was destroyed.

Davidson (16) made some experiments with the effect of vanillin on wheat in pots in Dunkirk clay loam. He obtained practically no effect with added amounts of vanillin less than 1000 parts per million. With vanillin used in amounts of 1000 parts per million without fertilizers a depression of 10 per cent. in growth resulted, and the effect with the soil limed was about the same; with fertilizers the results were irregular. No attempt was made to determine if the added vanillin remained in the soil or whether it was changed or destroyed. These results do not agree with those of field experiments made on the Dunkirk silty loam reported in this paper, in which vanillin and salicylic aldehyde proved harmful to cow peas, even when fertilized.

Funchess (21) studied the effect of several organic compounds, among them the aldehyde vanillin, on crops grown in pots, in several soils. He presents no data showing the fate of the compounds after their addition to the soil. Vanillin, in a Norfolk sandy loam, was quite harmful to oats in amounts of 500 and 1000 parts per million, but had only an indifferent effect in small concentrations. With a second crop grown after the harvesting of the first there was no residual harmful effect observed, indicating that the vanillin had been oxidized before the second crop was planted. A second application of vanillin before planting the third crop again caused considerable reduction in growth.

In another experiment, vanillin materially reduced the oats crop grown in this soil when used alone and with potash and phosphate and a complete fertilizer. Vanillin without fertilizers reduced green weight 66 per cent. with applications of 1000 parts per million and 42 per cent. with applications of 500 parts per million. Where the vanillin was used in pots with phosphates and potash the vanillin in amounts of 1000 parts per million reduced growth 69 per cent., and with 500 parts per million 50 per cent. Vanillin in pots with a complete fertilizer containing acid phosphate, sodium nitrate, and kainit, when added in concentrations of 1000 parts per million, reduced growth 40 per cent., and in 500 parts per million 32 per cent. While it appears from this experiment that the vanillin is slightly more harmful with phosphate and potash than in unfertilized soil, it is much less harmful in the soil fertilized with the complete fertilizer containing sodium nitrate. Funchess's results in the Alabama soil are in harmony with the results obtained by the writer on the action of this aldehyde in soils fertilized with sodium nitrate, previously reported. In the experiment with the Alabama soil the pots were planted to another crop, corn and cow peas, without any further addition of vanillin, but a second application of fertilizers was made. There was only a slight reduction in growth. This may be accounted for by oxidation or destruction of the vanillin, as four to five months intervened between the application of the aldehyde and the planting of the second crop. The alternate drying and wetting of the small volume of soil held by the pots, which in all probability occurred, would induce oxidation processes and thus change or destroy the vanillin. Again, in this work it is unfortunate that the absence or presence of the added substance was not determined from time to time during the experiments.

Other organic compounds were tested in the soil by Funchess, among them cumarin, which behaved somewhat as did vanillin, and dihydroxystearic acid, but they are not of interest in this paper dealing with the effects of aldehydes and therefore are not reviewed here.

Robbins (38) conducted some bacteriological experiments on the Alabama soils and secured results which seem to indicate that the disappearance of the added compounds vanillin, cumarin, pyridine, and quinoline was chiefly due to biological causes. The number of microörganisms increased greatly in the treated pots, following a depression in number which is analogous to that found in partial sterilization. The compounds added to sterile soils remained harmful to growth after a period of time, while the sterile soil which was inoculated with an infusion from normal soil showed no toxicity, the growth of the plants showing that the toxic properties of the compounds had largely disappeared. It is suggested by Robbins that the persistence of a compound—vanillin, for example—in some soils and not in others may be due to the fact that the vanillin-destroying organism is absent or to the fact that conditions are not suitable for its development or for the use of vanillin as a source of energy.[4]

Truog and Sykora (75) found vanillin, when added at the rate of 500 pounds per acre, in a sandy soil low in fertility and strongly acid in reaction, to be harmful to wheat grown in pots. Its harmfulness was overcome when the soil was limed, or when a complete nutrient solution was added. Vanillin added to a fertile silt loam produced no decreased growth. They also found guanidine to be very harmful. The effect of this strong basic compound was ameliorated by the addition of an acid kaolin to the sand culture. They concluded that chemical reactions are probably important factors in lessening the effects of harmful organic compounds in soils.

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[4] Since the preparation of this manuscript Floyd reports the results of some work with vanillin on citrus seedlings, in connection with investigations of the dieback of citrus fruits. In concentrations of from 39 to 1250 parts per million vanillin caused a shorter growth in stems and roots of grape-fruit seedlings; in the higher concentrations there was much surface injury of the roots. In amounts higher than 1250 parts per million there was much injury. The roots in all concentrations were discolored from a purplish brown to brown color. No gum was formed on the seedlings by the toxic action of vanillin (Floyd, B. F., "Toxic Effect of Organic Chemicals on Citrus," report of Florida Agricultural Experiment Station for 1916, p. 30 R.).

Thus, from the results of various investigations cited, it is seen that the effects of the soil aldehydes studied vary, depending upon the soil used and the method of study. However, it is shown that the aldehydes, salicylic aldehyde and vanillin, are harmful in soils in which they were not destroyed or changed by biological agencies. Before proceeding to give the detailed data showing the effects of the aldehydes studied, the results of a chemical examination to determine the occurrence and distribution of aldehydes in field soils will be presented.

OCCURRENCE OF ALDEHYDES IN GARDEN AND FIELD SOILS.

The discovery of salicylic aldehyde in the Mount Vernon gardens and the harmful properties of the aldehyde toward plants led to a study of the extent to which material of this type is likely to be encountered in soil investigations. In extending this study to many soils it was not feasible to examine large quantities of such soil, so that it was not possible to demonstrate clearly the identity of the aldehyde obtained, but it was possible so to treat a sample of soil as to obtain the compounds of an aldehyde nature contained therein, separated from compounds having non-aldehyde properties. This aldehyde material was tested as far as the quantity permitted for such reactions as are given by salicylic aldehyde; namely, coloration with ferric chloride, and the general aldehyde reaction with fuchsins reagent. In all cases the aldehyde material was subjected to the physiological test as to its effect on plant growth, using wheat seedlings in the well-known manner. The procedure employed in extracting the aldehyde material from the soil and the manner of testing it was as follows:

Twelve to sixteen pounds of soil were used in the examination for aldehyde. The soils were extracted with eight litres of a three per cent. solution of sodium hydroxide. The mixture was stirred for six to eight hours and, after settling over night, the liquid was poured off. The alkaline extract was acidified with sulphuric acid and filtered from the so-called humus precipitate. The acid filtrate was shaken out with several portions of ether, the ether extract combined and shaken with a concentrated aqueous solution of sodium bisulphite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combination with the sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid, and air was blown through to remove the sulphur dioxide liberated. This acidified solution, in which the aldehyde is now liberated from its combination with the bisulphite, was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation. There remained a small quantity of material, often resinous or oily in appearance.

This material was further purified by again taking up in water, extracting with ether, and the ether solution, after filtering, allowed to evaporate. Sometimes this operation was repeated. The purified residue contains the aldehyde material.

This aldehyde material was treated with a small quantity of water. The aqueous solution is frequently colored, and on evaporation a yellow oil is often noticeable, as would be the case if salicylic aldehyde were present. The odor of the latter is also sometimes observed, although in other cases other odors are perceptible, suggesting other aldehydes.

The fuchsine reagent was added to a portion of the solution, and to another portion a small amount of ferric chloride was added. Salicylic aldehyde, as mentioned, gives a violet color with ferric chloride and a pink color with the fuchsine reagent. Where both these reactions were observed the soil was considered as containing aldehyde. While the nature of the material is not thereby definitely shown to be salicylic aldehyde, yet the manner of isolation with ether and extraction therefrom with sodium bisulphite, together with the reaction shown with the fuchsine reagent, show the material to be an aldehyde, and the physical character of fluidity and the reaction with ferric chloride make it quite probable that in most of these cases salicylic aldehyde was under consideration. The amount obtained did not permit of further identification than is here given, especially as the main object was to determine the physiological property of the extracted material.

The main portion of the material remaining after making the above tests was dissolved or mixed with 250 c.c. of pure distilled water and the resulting liquid used as a culture for wheat seedlings in order to test the physiological effect of the extracted material from the soil. This was done with every soil examined, whether the above chemical tests were negative or positive.

In order to study the presence of aldehydes a number of soils were tested. Included in this test were a number of soils sent to this bureau from time to time by gardeners and greenhouse men. The soils submitted were garden and greenhouse soils, on which the owners had experienced some difficulty in producing vegetables or flowers. Often the soils had grown good crops, were intensively cultivated and heavily manured, and later failed. In this respect the conditions were similar to those on the Mount Vernon soil. This soil had been used for growing flowers and garden plants for a long time, had failed to show further response to manure, had been declining in productivity, and had been shown to contain salicylic aldehyde in the investigations reported. It seemed profitable, therefore, to include soils in this examination which in some degree had a similar history. The results of the examination of these soils, 14 in number, are given in Table I.

In addition to this adventitious examination of garden soils, a similar survey was made with soils collected in the open field by soil experts under instructions furnished them. Accordingly, samples of field soils were collected from various parts of the United States. A productive sample and an unproductive sample of the same soil type, either from the same field or at least in the same vicinity, were sent in for investigation. The history of the soils as to crops grown, fertilization, drainage, etc., was secured so far as available.

The result of this examination for the occurrence of aldehyde compounds in soils includes good and poor samples from many parts of the United States, comprising acid, neutral, and alkaline soils, soils of different cropping, different texture, drainage conditions, climatic conditions, etc. The results of the examination of these soils are given in Table II.

A total of 74 soils is described in the two tables. Of these, 14 are garden and greenhouse soils which had failed to grow good crops, and 60 are field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. In this connection, attention should again be called to the fact that the field samples were collected in pairs, one good and the other poor, of the same soil type and from the same field or locality, so that statements concerning productivity pertain to the relation existing between the samples of the same type.

TABLE I.

Results of Examination of Unproductive Garden Soil for Aldehydes.

No.	Soil	Location	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat	
1	Garden soil, loam	Mount Vernon, Va.	Flowers	Acid	+	Very harmful	Rich loam, well manured for over a century.
2	Garden soil, silt loam	Mechanicsburg, Pa.	Vegetable	Very acid	+	Very harmful	Poultry manure and commercial fertilizer used for 10 years.
3	Garden soil, loam	Washington, D. C.	Flowers	Acid	−	No effect	Heavily manured.
4	Garden soil, loam	Pittsburgh, Pa.	Flowers	Acid	−	—	Manured, responds to lime.
5	Garden soil, gray sandy loam	Philadelphia, Pa.	Garden crops	Acid	−	Harmful	
6	Garden soil, loam	Phœnixville, Pa.	Garden crops	Alkaline	−	No effect	Well manured, salt content high
7	Garden soil, red loam	Orange, N. J.	Vegetables	Acid	+	Slightly harmful	Rich loam, declining, manure ineffective.
8	Truck soil	Chester Co., Pa.	Truck crops	Alkaline	+	Very harmful	Commercial fertilizer and rotation, trucked for 20 years, crops now failing. Soil contains excess of salts (0.15 °/o); sub line also contains aldehydes.
9	Greenhouse soil loam	Arlington, Va.	Flowers	Neutral	+	Very harmful	Heavily manured.
10	Greenhouse soil loam	Arlington, Va.	Flowers	Neutral	−	No effect	Soil weathered for months since it had been used for floriculture.
11	Greenhouse soil raw loam	Arlington, Va.		Acid	−	No effect	Raw soil used in making soils Nos. 9 and 10.
12	Garden soil gray	Philadelphia, Pa.	Garden crops	Alkaline	−	No effect	Drainage poor.
13	Garden soil waxy black	Green Co., Ind.	Garden crops	Acid	−	No effect	Responds to lime and potash fertilizer.
14	Dark gray	Sanford, Fla.	Citrus	Alkaline	−	No effect	Calcareous soil.

TABLE II.

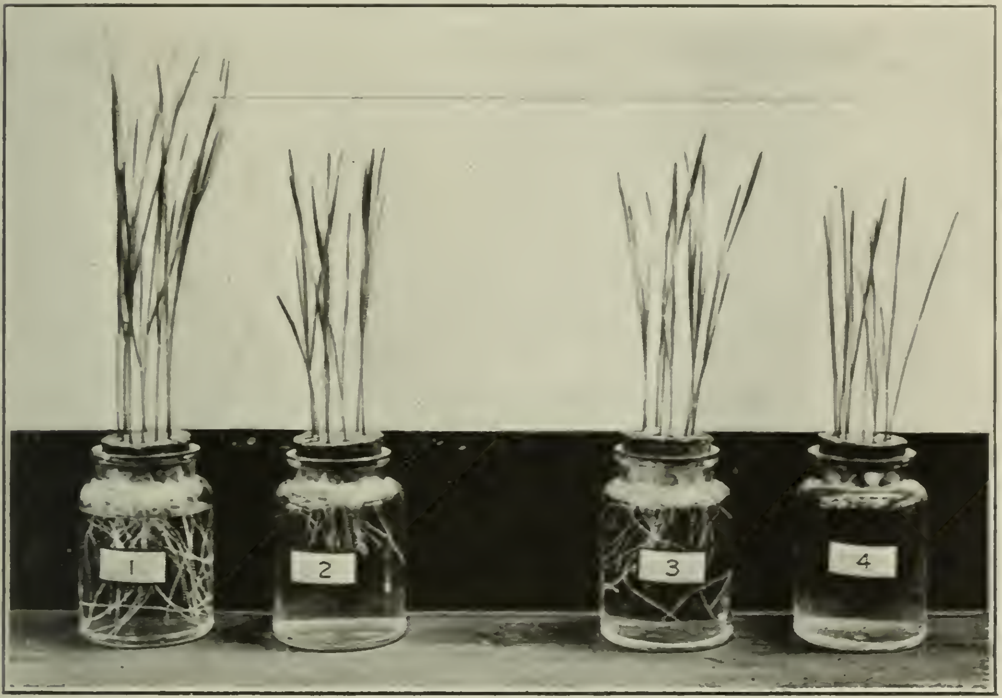
Results of Examination Productive and Unproductive Field Soils for Aldehydes.

			Productive				Unproductive			
No.	Soil type	Location	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat
1	Tifton sandy loam	Covington Co., Ala.	Corn	Slightly acid	−	Harmful	Corn	Slightly acid	−	Harmful
2	Huntington fine sandy loam	Pope Co., Ark.	Corn	Slightly acid	−	Slightly beneficial	Corn	Slightly acid	−	Slightly beneficial
3	Decatur clay loam	Chattooga Co., Ga.	Cotton	Acid	−	Not tested	Cotton	Acid	−	Not tested
4	Noesloe silt loam	Cherokee Co., Kan.	Wheat	Slightly acid	−	Beneficial	Corn	Slightly acid	−	Beneficial
5	Colby silt loam	Jewell Co., Kans.	Corn	Neutral	−	Beneficial	Wheat	Neutral	−	Beneficial
6	Osage loam	Greenwood Co., Kans.	Grass	Alkaline	−	Beneficial	Corn	Alkaline	−	Beneficial
7	De Kalb silt loam	Christian Co., Ky.	Clover	Neutral	−	No effect	Tobacco	Neutral	−	Slightly harmful
8	Miami loam	Genessee Co., Mich.	Grass	Slightly acid	−	Harmful	Wheat	Slightly acid	−	Harmful
9	Carrington silt loam	Goodhue Co., Minn.	Barley	Slightly acid	−	Beneficial	Grass	Slightly acid	−	Beneficial
10	Memphis silt loam	Lafayette Co., Miss.	Corn	Neutral	−	No effect	Grass	Acid	+	Very harmful
11	Summit silt loam	Cass Co., Mo.	Oats	Not tested	−	No effect	Wheat	Not tested	−	No effect
12	Aurora silt loam	Miller Co., Mo.	Corn	Slightly acid	+	Harmful	Millet	Slightly acid	−	No effect
13	Freehold loam	Monmouth Co., N. J.	Grass	Slightly acid	−	Beneficial	Corn	Slightly acid	−	Slightly harmful
14	Dutchess silt loam	Orange Co., N. Y.	Millet	Neutral	−	Slightly harmful	Grass	Neutral	−	Harmful
15	Norfolk very fine sandy loam	Pender Co., N. C.	Cotton	Acid	+	Harmful	Cotton	Acid	+	Very harmful
16	Champlain loam	Ashe Co., N. C.	Corn	Neutral	−	No test	Corn	Neutral	−	No test
17	Toxiway fine sand	Ashe Co., N. C.	Grass	Slightly acid	−	Harmful	Grass	Slightly acid	−	Harmful
18	Portsmouth silt loam	Perquimans Co., N. C.	Cotton	Slightly acid	−	Harmful	Corn	Slightly acid	+	Harmful
19	Miami stony loam	Oneida Co., N. Y.	Corn	Acid	−	Slightly harmful	Meadow	Acid	+	Harmful
20	Ontario loam	Oneida Co., N. Y.	Oats	Neutral	−	Slightly harmful	Corn	Neutral	+	Harmful
21	Muskogee silt loam	Muskogee, Co., Okla.	Peanuts	Acid	−	Beneficial	Cotton	Acid	+	Harmful
22	Berks shale loam	Lehigh Co., Pa.	Grass	Slightly acid	−	No effect	Grass	Slightly acid	−	No effect
23	Norfolk fine sandy loam	Georgetown Co., S. C.	—	Slightly acid	−	No effect	Corn	Acid	+	Harmful
24	Clarksville silt loam	Robertson Co., Tenn.	Wheat	Acid	−	No effect	Clover	Acid	−	No effect
25	Jordan loam	Cache Co., Utah	Oats	Alkaline	−	Beneficial	Oats	Alkaline	−	Beneficial
26	Salt Lake clay	Cache Co., Utah	Wheat	Alkaline	−	Slightly harmful	Wheat	Alkaline	+	Harmful
27	DeKalb silty clay loam	Preston Co., W. Va.	Grass	Slightly acid	+	Harmful	Fallow	Slightly acid	+	Harmful
28	Carrington silt loam	Dane Co., Wis.	Tobacco	Neutral	−	Harmful	Oats	Acid	−	Harmful
29	Sioux fine sandy loam	Buffalo Co., Wis.	Corn	Slightly acid	−	No effect	Rye	Slightly acid	−	No effect
30	Miami silt loam	Jefferson Co., Wis.	Corn	Neutral	−	Harmful	Alfalfa	Neutral	−	Harmful

These soils were all subjected to the method described for obtaining aldehyde compounds from soils, and the material thus obtained tested with the reagents mentioned. Five of the garden soils and twelve of the field soils gave an appreciable amount of aldehyde compounds when thus extracted, and this material gave positive reactions with the fuchsine reagent and with the ferric chloride.

An examination of the data in Tables I and II shows that the aldehyde from certain of these soils is harmful to growth, and that these soils behave in this respect like the Mount Vernon soil (Table I, No. 1, Fig. 1), which has been already more fully described and in which salicylic aldehyde of poisonous properties was demonstrated.

FIG. 1.

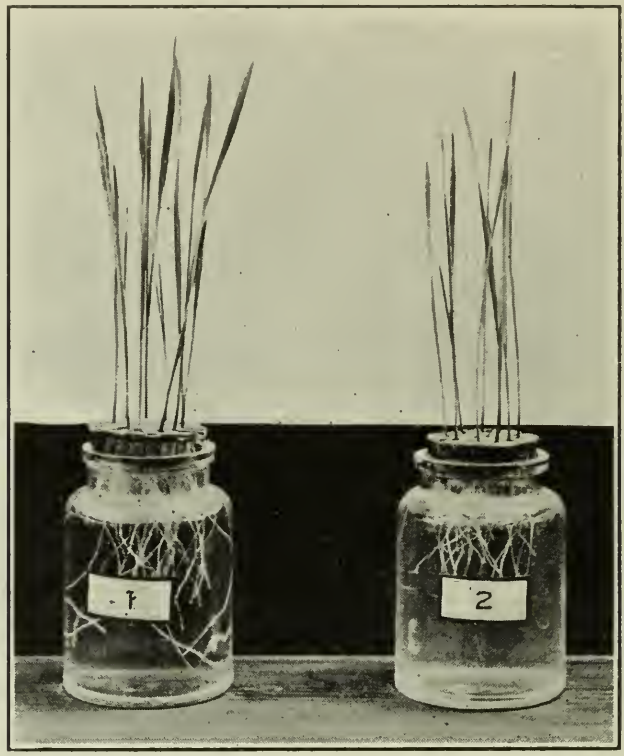


Effect of salicylic aldehyde extracted from Mount Vernon garden soil on wheat seedlings: (1) Nutrient solution; (2) nutrient solution plus salicylic aldehyde; (3) distilled water; (4) distilled water plus salicylic aldehyde.

In Fig. 2 is shown the effect of this material from soil No. 2, Table I. This has been used for gardening and trucking for the last ten years, and has been manured each year with poultry manure and commercial fertilizers. The soil in the last two years produced poor vegetables and truck crops, and corn failed entirely. The soil is grayish-yellow in color, is quite acid and low in organic matter. The separated aldehyde extract was harmful to the growth of wheat seedlings, causing a decrease of 33 per cent.

In Fig. 3 is shown the effect of the aldehyde extract from soil No. 8, Table I, showing an alkaline reaction. This soil had been growing vegetables and truck crops for 20 years with frequent use of commercial fertilizers. Corn, cabbage, and cantaloupes had failed in certain sections of the field for the last two years, whereas formerly the soil grew excellent truck crops of all kinds. The soil and subsoil were quite alkaline to litmus paper, and both showed the presence of considerable aldehyde material. This aldehyde reduced growth of the test plants by 26 per cent., both tops and roots being severely injured.

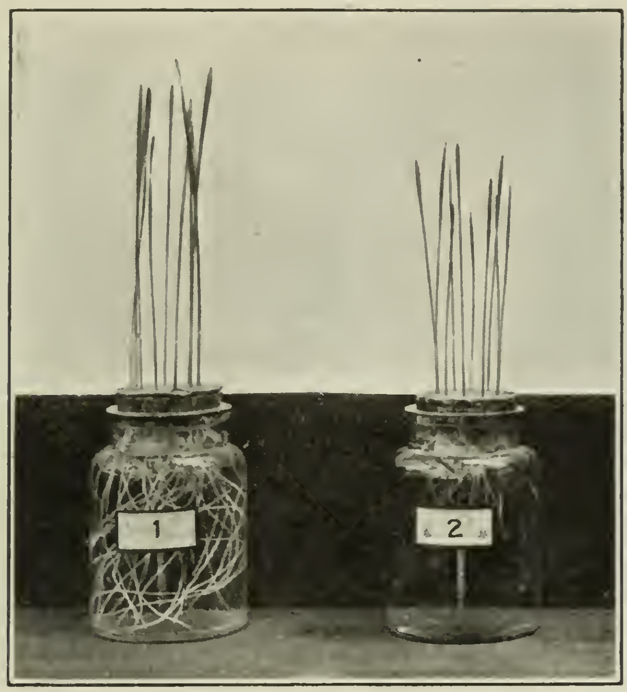
FIG. 2.



Effect of aldehyde extracted from garden soil (No. 2, Table I) from Mechanicsburg, Pa., on growth: (1) Distilled water; (2) distilled water plus aldehyde.

The heavily manured greenhouse soil (No. 9, Table I) is particularly interesting in that considerable aldehyde was found, whereas neither the raw soil (No. 11, Table I) nor similarly treated soil which had been used and then weathered for some time (No. 10, Table I) contained the harmful aldehyde material. This examination was made because the soil in question had been used on benches for floriculture and did not give good results. Soil No. 9, Table I, was a composite taken from two benches in the greenhouse where carnations and roses did not thrive. This contained aldehyde, which, when tested with wheat seedlings, gave reductions in growth of 35 per cent. Soil No. 10, Table I, had been previously used for greenhouse purposes and had been made in the same way by manuring heavily the raw soil, but without experiencing any difficulty. Since then it had been in a pile outside for several months. At the time of testing no aldehyde could be found, nor was the residue obtained harmful to the seedling wheat. Soil No. 11, Table I, was the raw soil as it was hauled from the field prior to the incorporation of manure in preparation for greenhouse use. No aldehyde could be detected in this soil, nor did such residue as was obtained show any harmful effect.

FIG. 3.

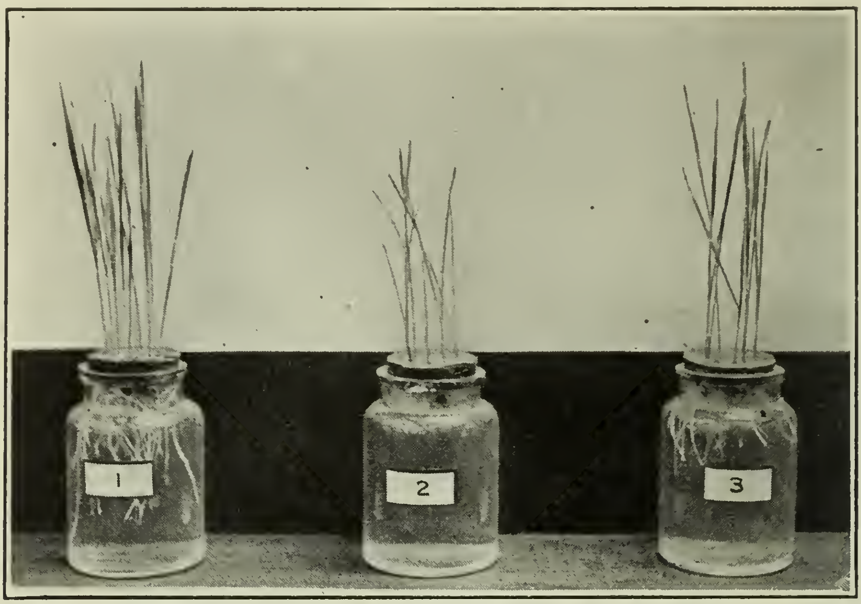


Effect of aldehyde extracted from a poor garden soil (No. 8, Table I) on wheat seedlings: (1) Distilled water; (2) distilled water plus aldehyde from garden soil.

Soil No. 19, Table II, the unproductive sample of Miami stony loam, contained aldehyde, and the depressed growth obtained is shown in Fig. 4, together with the effect of the identically extracted good field sample. The latter showed no aldehyde reactions, but, as seen from the photograph, it was, nevertheless, somewhat harmful—a fact which is recorded in the table.

Soil No. 20, Table II, the Ontario loam, unproductive, from Oneida County, New York, together with its good companion sample, presents an interesting story. In 1907 both fields were poor, unproductive soils. Both fields were manured heavily every year. One field responded to this treatment, the other did not.

Fig. 4.



Effect of substance extracted from poor and good Miami stony loam (No. 19, Table II) on wheat plants: (1) Distilled water; (2) distilled water plus material from poor soil containing aldehyde; (3) distilled water plus material from good soil showing no aldehyde reactions.

The field now good, represented by the productive sample, grew corn in 1907 and produced a poor crop. In 1908 the field was manured and planted to oats, giving a good yield. It was manured every year after this. In 1909 and 1910 hay was grown with good results, the largest crop being in 1910. In 1911 an excellent crop of corn was grown, and in 1912 oats were again grown with good yields.

The other field represented by the unproductive sample was in meadow in 1907 and gave poor yields. In 1908 the field was manured and planted to corn, which failed entirely. It was manured every year after this without good results. In 1909 oats were planted, but made very little growth. In 1910 and 1911 grass was sown and gave poor results. In 1912 the soil was heavily manured and again planted to corn. The yield of stover was very poor, and no grain was formed.

The laboratory examination of the two soils showed them to be neutral in reaction. The good soil gave no reactions for aldehydes when extracted for this purpose, but the extracted material was slightly harmful. The poor soil, however, gave considerable amounts of aldehyde material, and this was distinctly harmful to the wheat seedlings, reducing growth 28 per cent.

The unproductive sample soil No. 26, Table II, the Salt Lake clay, is from a poor spot in an otherwise good field. The remainder of the field is represented by the productive sample of soil No. 26, Table II, and was collected about 35 feet from the poor spot. The color of the soil in the poor spot is light gray, while the good soil is gray with a pink tint. This spot is generally bare and seldom produces a crop, while the remainder of the field is very productive, yielding from 20 to 30 bushels of wheat per acre. The drainage in the poor spot is poorer than in the remainder of the field. The subsoil of both good and poor soil is a light, calcareous clay. Both soils are alkaline in reaction, and both showed the same content of water-soluble salts (0.03 per cent.). The good sample contained no aldehydes, and such residue as was obtained proved only slightly harmful to wheat seedlings, whereas the poor sample contained considerable aldehydes, which proved very harmful to wheat seedlings in the cultural tests, reducing growth 30 per cent.

Returning now to a discussion of the data as a whole, it is shown that the aldehyde extract is uniformly harmful to the test plants. This is apparent from the next to the last column of Table I and the fifth and last column of Table II.

In the tables are also given the field record of the soils as to their productivity, the data being furnished by the collector. The garden soils (Table I) were all soils with which trouble of one kind or another had been experienced. In general, the data show that the soils containing the aldehyde were also poor soils in garden and field, with some few exceptions. One notable exception is found in the Aurora silt loam, good (No. 12, Table II), from Miller County, Missouri. This soil contained aldehyde, whereas the corresponding poor sample from another farm gave no indication of the presence of aldehyde. This observation was confirmed by procuring a new sample from the farmer on the good soil six months later. The other exceptions are the Norfolk very fine sandy loam, good (No. 15, Table II), and the Dekalb silty loam, good (No. 27, Table II), in which aldehyde was found, but it will be noticed that in both cases the poor soil contained the aldehyde also. It would appear, therefore, that both the good and poor soil samples contained some aldehyde. It might be further pointed out that in both cases the greater productivity of the sample designated as good is doubtless due to the direct fertilizing value of the applied manure, the less productive samples having no manure applied. That manure is not antagonistic to aldehyde is indicated by its presence in the exceedingly well-manured garden soils (Table I) (see notes in last column), as well as by some of the field results.

From these two tables it is at once apparent that only a relatively small number of the poor soils showed the presence of aldehydes, which means that the poorness of many of the soils must be attributed to other causes, since soil infertility may be due to a great many factors other than the presence of toxic compounds, and especially any particular toxic compound.

The material extracted in the aldehyde method, as in all these cases, was extremely small and gave no aldehyde reactions, but in some cases it proved harmful, nevertheless. What the nature of the harmful substance in these cases was it is impossible to state, as further study was excluded. If aldehyde was present, it was at least so small in amount that it escaped chemical detection; nor does the method wholly exclude the occurrence at this place of traces of other compounds. In the majority of cases the material was not harmful, occasionally even showing a slightly good or stimulating effect.

Seventy-four soils are described in the foregoing tables. Of these, 14 were garden and greenhouse soils which had failed to grow crops, and 60 were field soils, under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. These soils were all examined for aldehydes. Of the 14 garden soils, five contained aldehydes, and of the 60 field soils, 12 contained aldehydes.

(To be continued.)

DYESTUFFS.*

BY

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Mr. Chairman, Ladies and Gentlemen:

In addressing you this evening upon the subject of Dyestuffs, I am not unmindful of the wide extent of the subject and also of the very great amount of information and data, both general and technically special, that has been given to the public from various sources, since August, 1914.

During this intervening period, and particularly during its first twelve months, when there was manifested so much concern regarding the probable supplies of coal-tar colors for our several dye-consuming industries, the wildest rumors regarding the possibility of dye production in this country were current, and there was hardly a day but some new and far-reaching discovery was announced, in the columns of the daily papers, that would unlock the tightly-closed secrets of the German dye makers, and unlimited quantities of much-desired anilines would flow forth.

We know now that much of this wild publicity was the result of a total misconception of what dye production is, and the very great majority of those who were to relieve the serious dye situation are now at labor in other fields.

The dye industry, like many other fields of activity, has been developed by gradual stages through the years, and from the most modest beginnings. It has grown and increased in importance from the time when the artistic ideas of peoples were in a very crude state.

From the very earliest times of which we have record, there is evidence that certain coloring matters of organic origin were in use, the two most important being indigo and madder, and it is interesting to note that these two items have come down to us continuously to the present.

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* Presented at the Stated Meeting of the Institute held Wednesday, February 20, 1918.

It is not necessary to burden you with a list of those coloring matters quoted in the Scriptures, but it may be interesting to record the fact that in Europe, prior to 1600, the art of dyeing, even at that time had attained considerable importance on account of the skill of the dyers. There were currently employed at that period:

Indigo, Madder, Litmus, Brazil Wood, Lac Dye, Kermes, Buckthorn Berries.

These several dyewares, or the coloring matter extracted from them, were mostly used for dyeing woollen fabrics and linen.

During the long years between 1600 and 1860, there were gradual additions to this old list of natural colors, which then included besides Indigo, Madder, and the astringents—Sumac and Gallnuts—Peachwood, Camwood, Barwood, Sanders Wood (tropical woods); Cochineal (Guatemala); Fustic (Cuba); Weld Quercitron Bark (Pennsylvania); Cutch and Turmeric (Burma and Mexico). With this line of dyewares, the dyer was in a position to meet most of the demands made upon him for dyeing not only wool, but cotton and silk as well.

In certain localities, notably in parts of France, some coloring matters obtained from plants indigenous to the region in which the dyer worked, were used. Among these dyewares may be included safflowers and saffron, the former much employed for a most beautiful shade of pink, and the latter for a shade of yellow.

As the fame of the dyer's products and skill spread, the interest of dyers in other localities became excited and the desire to produce similar results was aroused. In consequence, the secrets of the dyer, handed down from father to son, were jealously guarded, so that competition might not be able to duplicate their work. We have evidence of this condition when we examine the recipes extant in old formula books of dyers of past generations, notably in the production of the so-called "spirits," those mysterious compositions of tin and certain acids, which were designated largely by misleading names.

The dyer of the period, prior to the introduction of the coal-tar dyes, was indeed a real master craftsman. While he may not have had the refined surroundings of the dyer of the present nor the highly developed scientific aids that are now so common, he produced results that are to be regarded as marvellous. When we read old notes and recipes, and bring to our mind the uncertain composition of the various "infusions" that the dyer employed, we are compelled to acknowledge that the workman of the period was one who really knew his trade.

The "infusions" or "liquors" made use of at that time, were largely weak liquid extracts made by boiling the crude natural dyewares with water, then straining and using the stock solution as the dyer's demands required. At other times, such as for logwood, a given amount of the ground wood was simply boiled out, and the total amount of infusion so obtained was employed for one batch of material to be dyed. This crude method of operating was the origin of the now highly-developed logwood industry which flourishes both in this country and in Europe, especially in France, from which country, the very finest logwood extracts have come.

There were other natural dyewares analogous to logwood, which occupied a prominent position in the catalogue of active coloring matters, and which include peachwood, barwood, sanders wood, and other similar woods, the majority of which are natives of the tropics. They were chiefly used for producing red, brown and many compound shades upon wool in combination with logwood. These woods were imported and ground, and the ground or rasped wood was sold to the dyer, who made the infusions as his requirements called for. Some of these now scarce and curious dyewares were used in Philadelphia even as late as 1895, where they were employed for producing shades upon heavy carriage robes, and in dyeing seal plushes. From that time until the outbreak of the war, the decline in the use of those products was rapid and complete. When the war curtailed many of the artificial colors, the dyers had to fall back upon these antiquated coloring matters, and after a time, some were imported and sold at unheard-of prices on account of the great demand and scarcity of stock. Afterwards, when domestic producers of artificial colors began to make deliveries, the market for the older dyewares fell off again. It is curious to note, however, that during the "dyestuff famine," when these antiquated coloring matters were brought to light, very few dyers knew anything about their application, and, as a consequence, the dyed material that was delivered from mills did not measure up to the usual current standards for fastness, and therefore, dyes were condemned offhand, when, as a matter of fact, the fault was not with the dyestuff, but with the inexperience of the dyer, due to his unfamiliarity with the dyestuff he was using.

There are to-day many experienced cloth dyers who are expert in the application of logwood—for be it remembered that logwood has always been a standard dyeware for black on wool, and against which artificial blacks for the same purpose are judged—and these same dyers are absolute failures when it comes to using other colors. The same remark applies with greater force to the dyeing of silk. There are no dyestuffs of coal tar origin that can duplicate the well made logwood blacks on this fibre. Black dyeing in the silk industry is a trade by itself, and deservedly so.

Indigo has been handed down to us from the earliest times as the one blue color that has been regarded as having a degree of fastness far in excess of any product yielding the same shade. It is a native of certain portions of the tropics of both hemispheres, but the greatest amount of natural indigo has by far been produced in British India.

Indigo, as it appears in commerce, is the blue coloring matter obtained by oxidizing the juices of the indigo plant. The plant at maturity is cut and carted to the indigo factory where it is placed in huge vats, water run on, and the whole allowed to ferment. At the proper stage of fermentation, the liquors containing the indigo in a chemically reduced state (indigo white) are run off and agitated, either by being whipped by hand or by revolving light paddle wheels. This agitation causes atmospheric oxidation of the indigo white, which is soluble, to indigo blue which is insoluble and precipitates. This precipitaton is then filtered and the cake pressed, then cut to proper size and branded while still moist, and finally dried. It is then ready for the market.

Indigo as a source of blue color, for textiles, has had an unbroken period of use for centuries. It is employed in dyeing both wool and cotton; the former by means of both so-called "vats" and as "extract," the latter always in the vat. Vat dyeing means that the indigo is reduced to the state of indigo white and then subsequently oxidized to indigo blue on the fibre. "Extract Blue" is dyed by means of a solution of indigo in sulphuric acid, formerly called "chemic," and in later years more carefully prepared by purifying the sulphuric acid solution of the indigo. A highly-refined dry indigo extract is sold as Indigotine, but it is in reality only a disulphonic acid of indigotine—the real blue color of indigo in soluble form.

Madder is another of the natural dyewares that has been in use for centuries, being employed most commonly for the production of reds—the red which we are most familiar with being termed Turkey Red. Formerly, and up to the recovery in 1868 of artificial alizarine by Graebe & Lieberman, its cultivation and preparation for market was a most important and flourishing industry. When artificial alizarine became a commercial reality, the madder industry rapidly declined to very small proportions, and as a dyeware, it is no longer to be considered.

The several coloring matters to which I have directed your attention, occupying positions of first importance in the dyer's art, are mentioned for the purpose of preparing the way to the serious consideration of the dyes of artificial origin, and by which the great majority of the older dyes were completely displaced.

The first dyestuff of artificial origin is the well-known Perkins' Violet, and its discovery in 1856 paved the way for rapid strides in organic chemical research that has continued from that date to the present time, and the number of patents granted by various industrial countries attest the activity of chemists in the direction of dye production, although not every patent granted represents a dye that has attained commercial interest.

The more important artificial discoveries may be briefly summarized as follows:

Perkins' Violet or Mauvein (Epoch)	1856	
Fuchsine or Magenta	1858	(Hofmann)
Aniline Black (Epoch)	1862	(Lightfoot)
Nicholson's Blue	1862	
Methyl Violets	1866	(Poirrier)
Safranine	1868	
Artificial Alizarine	1868	(Graebe and Lieberman)
and its manufacture in	1869	
Indigo Blue from isatin	1870	
Eosine	1874	
Cachou de Laval (first sulphur color)	1873	
Triphenylmethane Dyes	1876	
Methylene Blue	1877	
Fast Red	1877	
Azo Scarlets	1878	
Propiolic Acid for Indigo	1880	
Congo Red (first direct or substantive color)	1884	

Tartrazine (first fast acid yellow for wool)	1885	
Primuline and the "ingrain" colors	1887	
Carbazol Yellow	1888	
Diamine Fast Red F	1889	
The Thioflavines	1889	
Indigo from Phenylglycocol	1890	(Herman)
Cyanine	1891	
The Rhodamines	1893	
Vidal Black (first sulphur black)	1895	
Synthetic indigo, vat colors, etc.		

This list could be greatly augmented but it is sufficient to indicate the gradual extent of industrial and chemical research that has developed the great number of dyes that find use in some or all of the industries employing coloring matters.

The particular branch of dye research that includes the so-called azo colors, deriving its impetus by the discovery of Peter Greiss in 1862, has been most productive of results and for the time engrossed the attention of the great majority of dye chemists, with the result that there were innumerable products given to dyers that traced their origin to the Greiss reactions. This particular group of dyes—Azo dyes—is chemically subdivided into thirteen divisions, and in their extension and development there has been made necessary a vast amount of chemical research covering the production of those raw materials that are necessary for each particular dye. This phase of dye chemistry has been to a very great extent neglected in this country, but during the past three years it has been receiving a degree of attention never before attempted in private laboratories, works' laboratories and in colleges.

In the operation of dye making, certain raw materials are necessary. These raw materials are obtained in the first instance from certain distillation products obtained from coal tar; the most important for the purpose of illustration are benzol and naphthalene.

From benzol there are obtained a succession of secondary products each the result of a definite reaction, and each possessing certain properties.

From naphthalene there are also obtained by various reactions a number of products aggregating at least one hundred and seventy-five, and each of which possesses properties that make it useful for certain further reactions. If we study the chemistry of several of these benzol or naphthalene derivatives, we will at once be impressed with the immense amount of painstaking research work that must have been done in order to ascertain the properties of each product, and the possibilities of combining each of them with other dissimilar bodies, for the purpose of obtaining a dye or coloring matter different from any other before produced. It is this constant investigation that has been at the bottom of the seemingly endless array of known dyes.

If the dye chemist has only to give his attention to combining various raw materials, his work is extremely simple, but where he has to work out the production of new raw materials, then his work becomes extremely complicated.

In studying the chemistry of the commercially useful derivatives of naphthalene, mostly sulphonic acids, we are at once impressed with the limited sphere of labor undertaken by the investigators, and a digest of the patents will show that the labors of these investigators have been quite active within these limits. Each investigator has concentrated upon some one, or possibly two, groups of colors, and their necessary raw materials, leaving to others similar work along diverging lines.

The group of azo dyes includes the greater number of dyestuffs that are available for cotton and wool, and for a long time after the classical discovery of Peter Greiss, occupied the attention of many chemists, with the result that a very extensive range of colors were produced with which the dyer was enabled to obtain shades of almost every conceivable hue.

One of the most important discoveries was the production of the so-called azo scarlets, which, in a short time, completely displaced cochineal. These original scarlets were later considerably improved upon, and brilliant shades were made possible possessing extreme fastness to light. Several of these scarlets are much employed in other industries, notably for the staining of paper.

The ultimate production of wool blacks marked the beginning of a revolution in dyeing certain textiles, which were formerly dependent upon logwood, and in time, the gradual decline of this latter dyeware became quite noticeable.

It is unnecessary for me to dwell upon the technical details for the production of these various products, since the outlines of the most important may be found in many treatises and in the patent literature.

After the discovery of Congo Red, in 1884, there was an immediate concentration of chemical endeavors upon the group of substantive dyes—dyes that colored cotton without a mordant—the result being a long line of products that at once gained recognition throughout the world. Some of these dyes are remarkable from the fact that they are capable of dyeing corresponding shades upon both cotton and wool, thereby opening the way for a valuable line of dyes, known as "union dyes," with which both of these fibres may be dyed the same shade in the same bath. This is of great commercial importance, inasmuch as it permits the manufacture of cotton and wool mixed goods that were not theretofore possible, except with considerable trouble.

There are many wool dyes that partially stain cotton, and also many cotton dyes that only slightly stain wool. The dyer, therefore, has at his command the means, by a judicious admixture of these two classes of dyes, of producing a combination of dyes that will enable him to dye union goods with the greatest ease. Most of these combinations dye the cloth in a bath fortified only with a small amount of sulphate of soda.

One of the most important, far-reaching dye discoveries was that of an Englishman—Green—in 1887, who produced a series of dyes known as "ingrain colors," and which at once gained a strong foothold in cotton mills on account of the then remarkable fastness of the shades produced. The most important dye of this group is known as primuline, and occupies a prominent position to this day as a source of red for cotton. It was the first dye to serve as a substitute for alizarine on certain classes of goods. Primuline is dyed upon cotton by the so-called "three-bath" process, which provides for the diazotization of the color on the fibre and its final development with a suitable developer, the most common being beta-naphthol, and produces the red above referred to. This group of colors was first limited to a few shades, possibly six, none being either a blue or a black. This disadvantage was at once apparent, and stimulated research, so that in due time diazotized blacks and blues came upon the market. The blacks appeared to offer particular advantages, especially as competitors of aniline black for hosiery dyeing. Indeed, a number of the best known brands of hosiery on the market are dyed with developed black.

The industry of the sulphur colors commenced by Croissant &

Bretoniére in 1873 has been greatly extended, and from which has been given a great number of dyes of the utmost importance. Their field of usefulness is almost confined to the dyeing of cotton. The blacks of this group have, together with the diazotized blacks, been the active competitors of aniline black, while the sulphur blues have, in many instances, replaced indigo for certain lines of cotton manufacture. The sulphur color industry is actually the starting point of the now firmly established " vat color " industry, although but few of the vat colors are made by any of the processes used in producing sulphur colors. The extensive group of vat colors includes a considerable number of dyes that are remarkable for their extreme fastness, and it was the general use of these dyes that gradually educated the people as to what a really fast color is.

The so-called vat dyes are divided into two main groups designated respectively Indigoid dyestuffs and Anthrachinone. The chemistry of both of these two groups is rather complicated and it will serve no useful purpose by going into the details of the reactions. For convenience, however, the following classifications may be introduced:

(*a*) INDIGOID DYESTUFFS.

(1) Indigo Group,
(2) Ciba Violet Group,
(3) Thioindigo Group,
(4) Indi Rubin Group,
(5) Thioindigo Scarlet Group,
(6) Ciba Scarlet Group.

(*b*) ANTHRACHINONE DYESTUFFS.

(1) Indanthrene Group,
(2) Flavanthranone Group,
(3) Benzanthranone Group,
(4) Anthrachinonimide Group,
(5) Acylaminochinone Group,
(6) Anthrachinonacridone Group,
(7) Vat dyestuffs of unknown composition.

(*c*) VAT COLORS CONTAINING SULPHUR.

(1) Anthrachinone Bodies,
(2) Carbazol Bodies.

This particular group of dyestuffs has excited remarkable interest ever since they were put upon the market; not alone from the chemical standpoint, but also from the fact that the practical results obtained from their use enabled manufacturers of cotton goods to greatly extend their line of woven and printed novelties, carrying at the same time a guarantee as to fastness and durability of shades that startled the industrial world in those lines of cotton manufacture known particularly as wash goods, ladies' and children's summer garments, men's shirtings, madras cloth and similar fabrics, carrying shades of blue, red, pink and combinations that emerged from the laundry quite intact. The study of the vat colors is most interesting. It should be borne in mind that the great majority of the patents granted for these particular colors are still in force and this fact alone is likely to mitigate against the possibility of the more important of the dyes so protected being manufactured in this country, even after the present war is terminated. There is every reason to believe that the German holders of patents for these valuable dyes will exert every effort to retain the manufacture of these dyes for and in Germany, and that it is hardly likely that licenses will be granted to American dye manufacturing plants permitting of the manufacture of even some of the most wanted of this group of colors. This condition, however, should not prevent a special effort being made on the part of dye chemists, professors of organic chemistry and advanced students of that particular branch of organic chemical work from devoting their undivided time and attention to the investigation of problems aiming to the production of further additions of dyes to this important group of colors. This is a most prolific field and one worthy of very serious thought on the part of chemists.

In this particular connection and relating very closely to this same group of coloring matters may be mentioned work done within very recent years. I take the liberty of making reference to a particular blue that requires as one of its chief raw materials a substance that has heretofore been regarded as an industrial nuisance, but which, due to the painstaking care of the investigating chemists, has been made available for the production of a coloring matter that possesses a shade equal to, and properties excelling in fastness those of indigo. I refer to carbazol, which, prior to this time, had been of no commercial or industrial value whatever, which has been found closely associated with anthracene as an impurity and from which latter it has to be separated by a process fraught with some difficulties. Carbazol has been made available for textile purposes by being converted into the blue dye applied in a manner similar to indigo in the "vat," and which produces indigo shades from the lightest to the darkest with great facility. For its production it is simply a matter of obtaining carbazol and when this product is secured in sufficient quantities there is no doubt but that the dye industry and that portion of the textile industry most interested will receive a great impetus.

In mentioning carbazol as a prolific field for chemical investigation, I might also include a number of equally well known and troublesome organic impurities found in other coal-tar distillates, which only await the attacks of the painstaking industrial chemists to find ways for their commercial utilization.

At this point the lecturer directed attention to a number of illustrations, several of which are printed herewith. The first was a diagram of a coal tar tree showing the general relationship that the finished dyestuffs have towards coal tar. By this tree we immediately grasp the idea that upon the destructive distillation of tar, certain prime raw materials are obtained, which, when subjected to further chemical treatment, are converted into the so-called intermediates that the dye maker employs for the production of the finished dyestuff. Coal tar itself is a by-product of the destructive distillation of coal either from the illuminating gas making process or from other operations where tar is recovered. During the process of distillating coal, illuminating gas is obtained, and during the operation of washing this gas ammonia is recovered. The residue remianing in the gas retorts is coke. When coal tar itself is subjected to destructive distillation it breaks up into a large number of raw materials, including Benzol, Carbolic Acid, Cresoles, Naphthalene, Anthracene, heavy oils, and leaves a large residue of pitch, the exact composition of which is known to vary, but which is still a subject of fruitful investigation by chemists.

The next diagram herewith reproduced (Fig. 1) shows graphically the average percentage composition of coal tar. Each square represents one per cent. The small amount of phenol or carbolic acid actually present in tar is indicated as well as the small amount of anthracene. It is this small amount of anthracene that carries a small, though available, amount of carbazol, to which I have previously alluded.

Figure 2, herewith, is a diagram showing the average quantity of distillates obtained from 2000 pounds of coal, together with the quantities of a few of the important dyestuffs which some of these distillates produce.

Figure 3 shows the sequence of events for the conversion of Benzol and Toluol into the well-known dyestuff magenta or fuchsine.

FIG. 1.

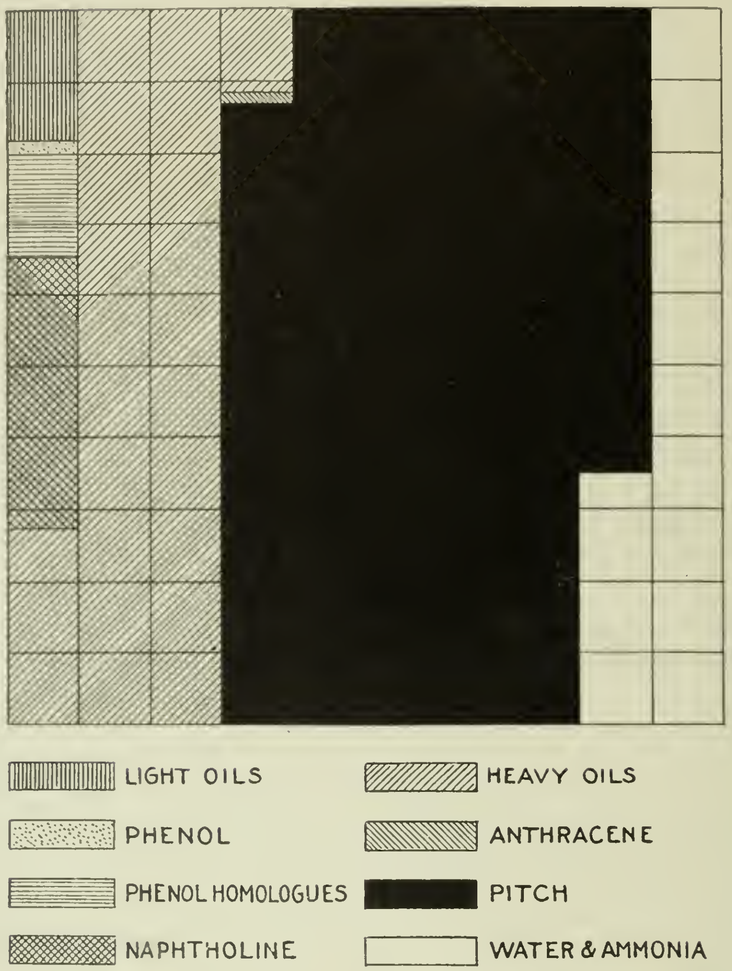
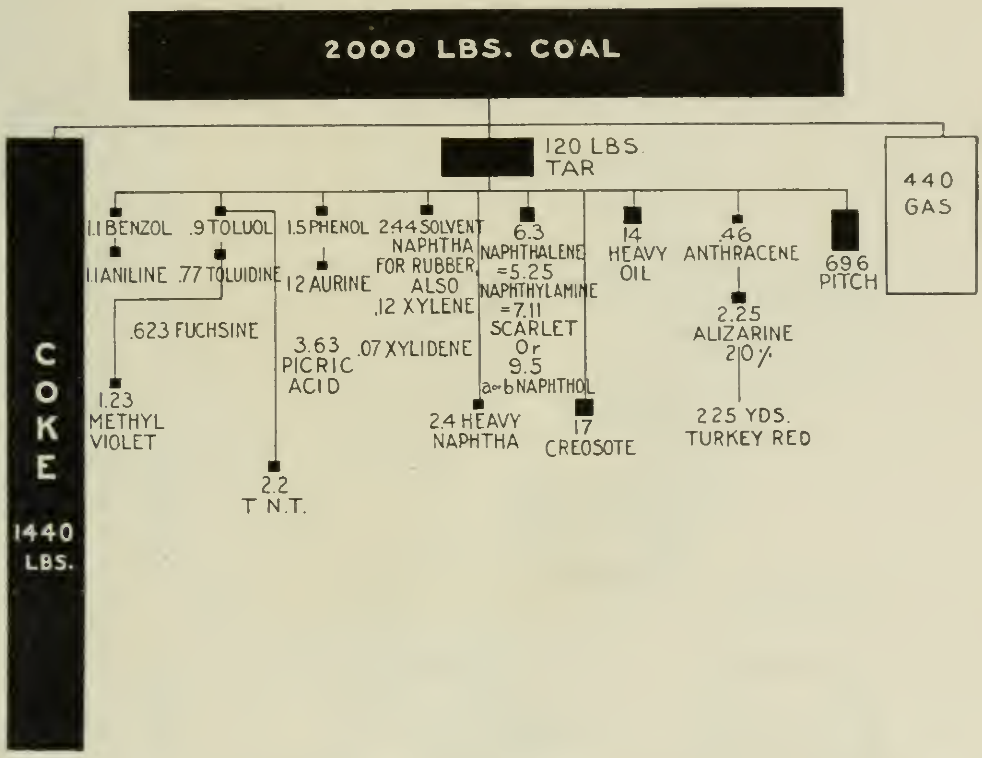


Figure 4 represents the chain of operations necessary for the conversion of the primary raw material—naphthalene—into Naphthol Yellow.

Figure 5 is of particular interest and shows graphically the so-called aniline process for the manufacture of synthetic indigo, from which we see that there are three primary methods having this object in view, all of which, however, aim to produce Phenolglycene, which is then subjected by one of three processes, according to patent limitations, into Indoxyl, and this latter product is then, by the oxidizing influence of the air, converted into indigo.

The so-called naphthalene process is shown in Fig. 6. This process has for its object the conversion of naphthalene into indigo and is known as phthalic acid process. The main product obtained is phenylglycine-o-carboxylic acid, which is fused with caustic soda producing indoxyl, and this latter by oxidation is changed into indigo.

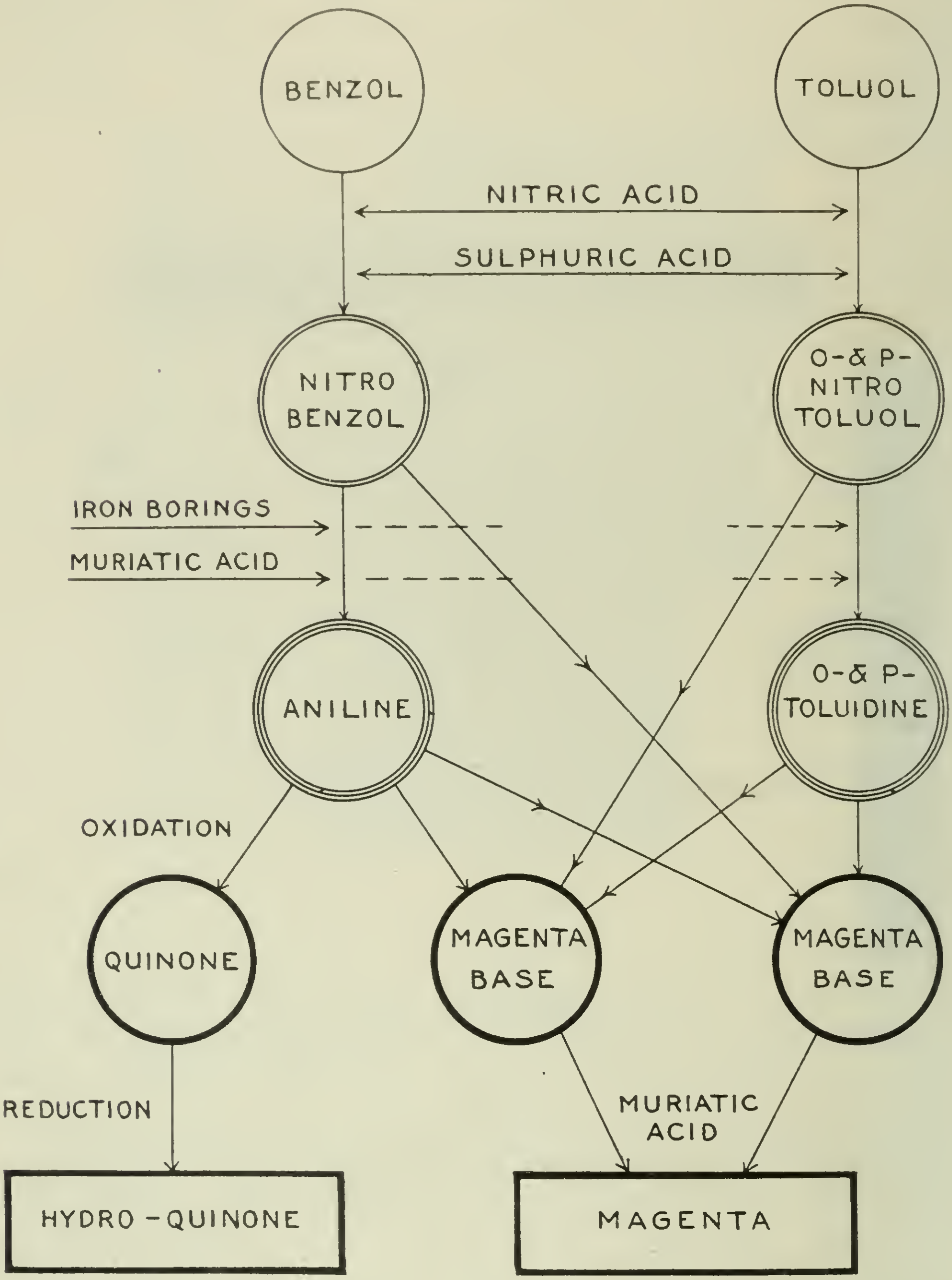
FIG. 2.



These several Indigo processes which I have shown are rather complex, but this complexity need not stand in the way of well-directed students in our organic chemical laboratories for undertaking the work under competent directors. There is not the slightest doubt but that investigating students equipped with personal laboratory manipulating ability and supplied with the necessary patent literature, should be able to carry out, first upon a laboratory and second, on a semi-factory scale, every operation involved in the production of this most important coloring matter, and the practical technical information thereby gained would be of the greatest value for further industrial research.

There were also shown a succession of diagrams illustrating graphically the manufacture of naphthol black, which includes the manufacture of beta naphthol, the conversion of beta naphthol into R-salt and G-salt, which are formed simultaneously and separated finally as shown in Fig. 7, and the conversion of the R-salt into the complete dye.

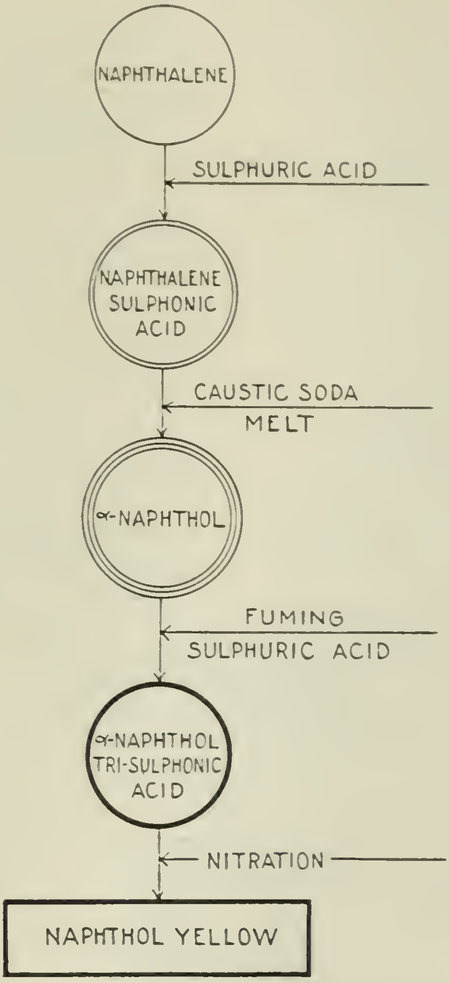
FIG. 3.



The manufacture of cyanol was illustrated by a succession of slides showing the production of crude benzaldehyde, the conversion of that substance successively into nitro-benzaldehyde, amido-benzaldehyde and oxy-benzaldehyde.

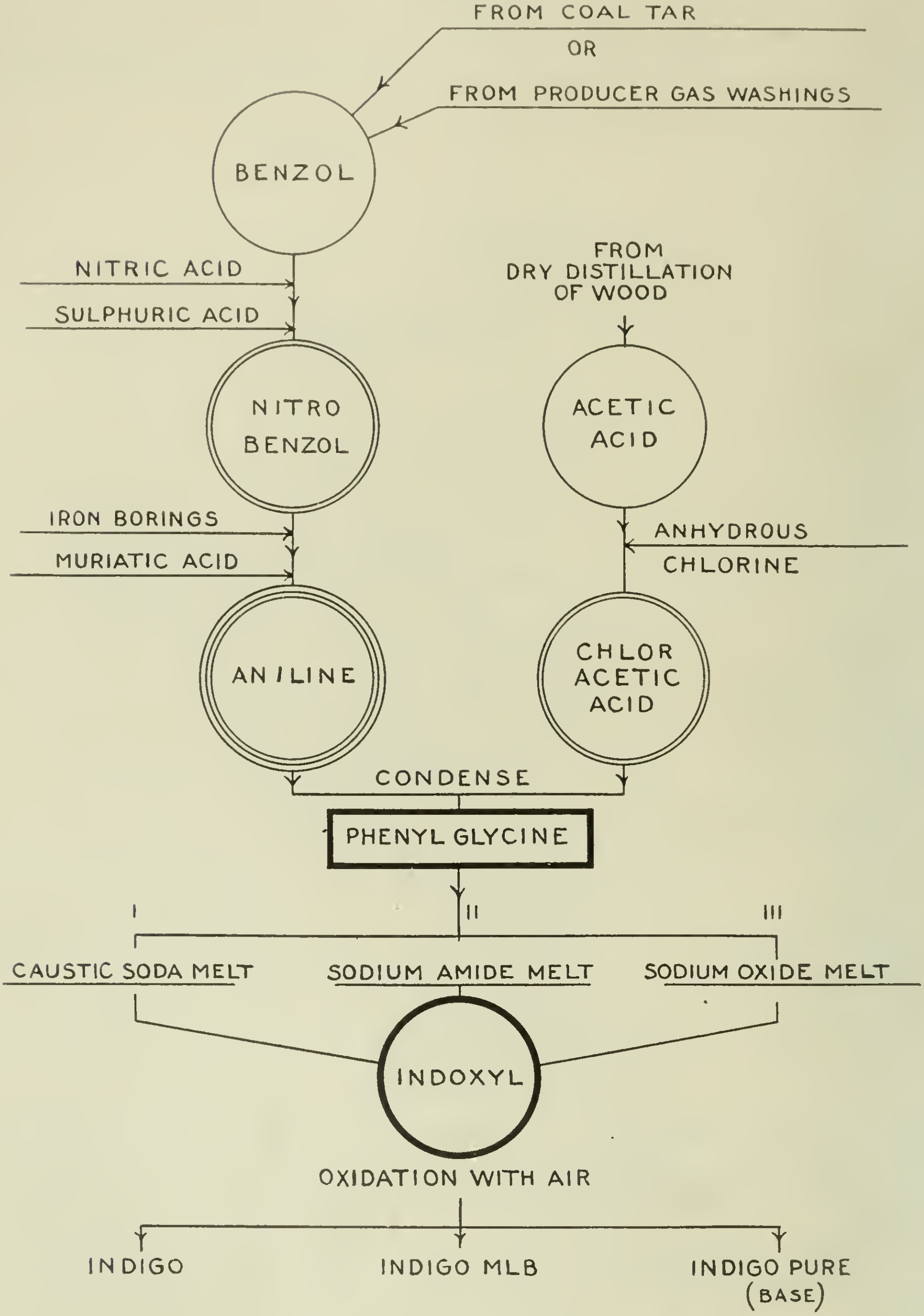
There were also shown illustrations of the process for the production of ortho-nitro-toluol, its conversion into ortho-toluidine and the ethylating of the same, and finally as shown in Fig. 8, the condensing operation and finishing of the completed dyestuff.

FIG. 4.



From an inspection of the several figures, we are impressed with the fact that dye manufacturing is not entirely chemistry, but is an industry that depends very largely upon the ability of the chemical engineer specially trained in dye making and dye-works equipment. After the preliminary outline of the process has been worked out, the results of his labor are taken up by others in the plant and gradually brought to manufacturing perfection, and it depends in a great measure upon the commercial importance of the dye in comparison with dyes known prior to

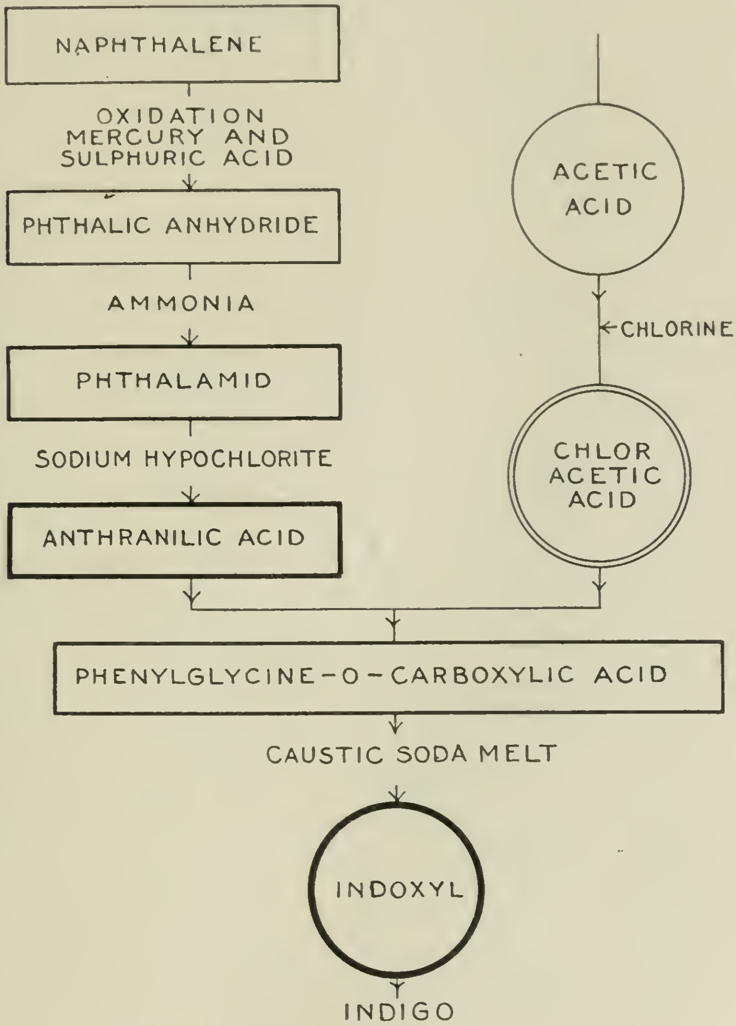
FIG 5



this discovery. If it possesses properties of fastness not assured by the older dyes, its field of usefulness is thereby enhanced.

In the ordinary course of dye manufacturing as carried out in the large color works abroad or in the more important dye manufacturing plants in this country, the work is divided about as follows:

FIG. 6.



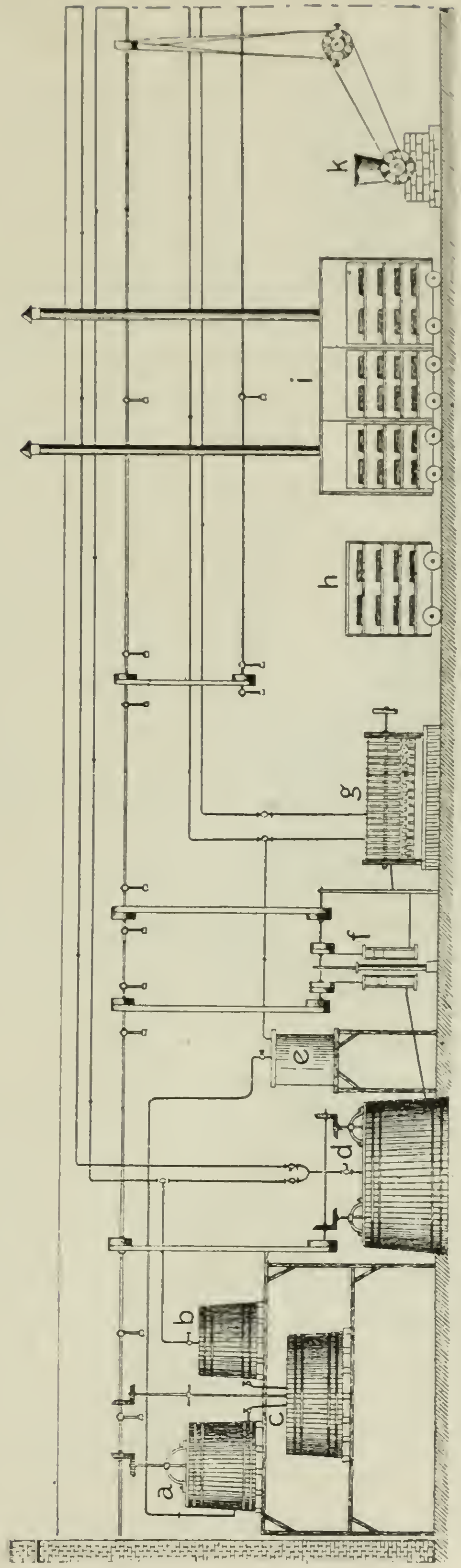
First, *Research Chemists.*—These are men with university training. As a rule they enter the dye works under rather humble conditions until they "find" themselves. Generally they specialize in one and sometimes in two groups of colors and it is seldom that they depart from the confines of their chosen specialty. It is they who experiment and work out what may ultimately appear on the market as a new dye. Their compensation is rather low; lower than men holding corresponding degrees from American universities. Their ambition is to make discoveries that will yield them royalties on account of their discoveries being good sellers. When a man has made a few discoveries and his dyes are on the market his income in the form of salary and royalties gradually increases and he becomes more or less a fixture in the research department. Ample evidence of this is to be found by carefully inspecting the names of patentees of dyes during the last three years, when we find that the same name occurs at various intervals, and, except in a few instances, is connected always with the same firm.

Second, *Factory Chemists*.—These men are also university graduates, but for one reason or another are less adapted to research work, or do not care for the restraint incident to chemical research. It is they who take up the work where the research chemists leave off. They adapt the chemical discoveries and reactions to factory conditions, and in most instances are the dye production supervisors; they are not foremen. Some of them may have under them two or three departments, for which they are responsible. As a rule it is from the ranks of these chemists that the superintendents or technical directors are obtained.

Third, *Chemical Engineers*.—Owing to their particular training and abilities, these men are responsible for the particular design and installation of the necessary machinery required for manufacturing the various dyes as the results are obtained from both the research chemists and the factory chemists. As a general rule, after the identity of the dye has been proven by the research chemist and after the factory chemist has worked out satisfactorily the sequence of the several operations necessary, even to the production of batches of fifty to one hundred pounds, or even more, and the dye has been demonstrated to be a promising one, it is then that the chemical engineer steps in and designs the plant for its commercial production upon a full factory scale.

Fourth, *The Engineers*.—The engineer department of a dye manufacturing plant goes beyond the corps of chemical engineers, although in some instances these departments may over lead. The engineers, of necessity, are more familiar with the construction of the individual units comprising the plant than the chemical

FIG. 7.



NAPHTHOL BLACK MANUFACTURE.

a, Vat for diazotizing the b-naphthylaminedisulpho acid; *b*, vat for dissolving the a-naphthylamine; *c*, vat for producing the amidoazonaphthalinedisulpho acid, and for diazotizing the same; *d*, vat for combining the diazoazo body with R salt; *e*, vat for producing R salt solution; *f*, duplex pump; *g*, filter press for the finished naphthol black B.; *h*, truck for the moist dye; *i*, drier; *k*, grinding mill.

engineers. It is the engineer department that takes care of the construction of the elements of the plant called for by the chemical engineer and factory chemist and whose advice and assistance is at all times encouraged when necessity requires.

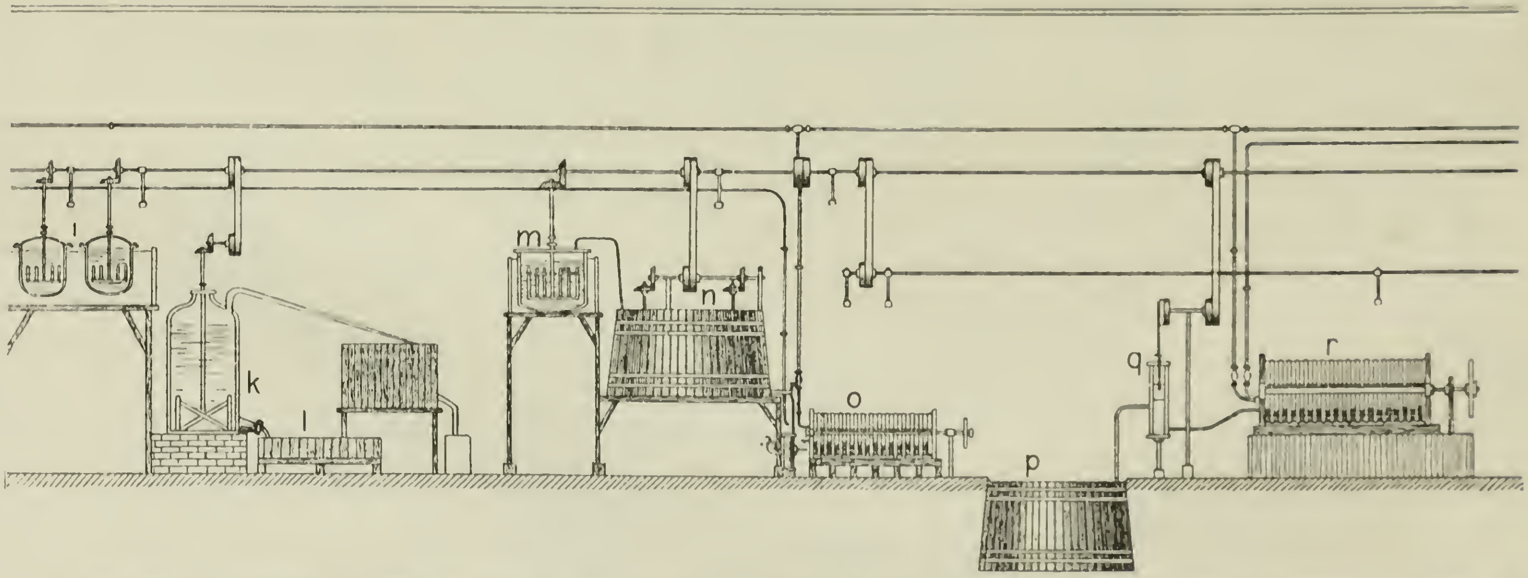
One thing is to be constantly kept in mind, however, regarding the so-called efficiency of German dye plants and that is the utmost care taken by the management to prevent undue intercourse and familiarity between those who comprise the several main departments. There seems to be, in fact there is, a sharp line of demarcation which keeps the various professional groups sharply separated. Unlike the prevailing custom in well-managed American plants, there are seldom, if any, general conferences that have to do with increasing the proficiency of the various departments. In most of the larger German color works there is rather a dense atmosphere of association difficult to penetrate and the existence of which only tends to retard rather than advance the particularly high degree of professionalism. This may be contrary to many pre-conceived notions gained by the American public, but it is a fact, nevertheless.

In dye establishments, distributing plants and similar commercial enterprises, the technical staff may be conveniently divided into two broad groups as follows:

(1) *Textile Chemists,* who specialize more or less in wool, cotton, silk, union goods, etc.—In some of the larger establishments men to fill these positions have been selected from the ranks of the salesmen who may have had previous mill experience, or from graduates of the various textile schools.

(2) *Dye Laboratory Chemists.*—These are usually boys or young men who entertain the idea that they are chemists, but whose preliminary education combined with lack of chemical training, enables them to discharge the duties only of dyer on a miniature scale and consequently they become standardizers or simply shade matchers. These young men become very expert in compounding the dyes of the firm for which they worked and in matching the colors of the firm's competitors. Generally it may be regarded as a mistake for a young man with chemical ambition to lose himself in a standardizing or shade-matching laboratory of a dyestuff house. There is little or no chemical work to be performed, and any knowledge that he may have upon this sub-

FIG. 8.



i, Kettles for condensing oxybenzaldehyde with mono-ethyl-o-toluidine; *k*, still for recovery of unconverted ethyltoluidin; *l*, filter for the condensation product; *m*, sulphonation kettle; *n*, vat for diluting and oxidizing the sulphonation; *o*, filter press for lead sulphate; *p*, neutralizing, and salting-out the dyestuff; *q*, filter press for the finished dyestuff (cyanol).

ject will certainly become stale, since no opportunity is afforded for him to exercise his chemical skill. Except in very few instances have such men ever become valuable technical men in the broad sense of the word, that is, men who are competent to go out into the dye houses of the firm's customers and solve difficult problems in the practical application of dyes or to seek the cause of the trouble, when, through one fault or another, the dyestuffs failed to do their work properly.

It is here that I believe many of our textile schools make the mistake of not suggesting to their dyeing students that they should take up the study of dyeing along some one restricted line and specialize in that. For example, wool. It is manifestly impossible for a man who is a wool dyer to be at the same time a skilled cotton dyer or a skilled silk dyer. I mention these points in order to direct your attention to the circumstances surrounding the employment of chemists in the dyestuff industry. It is an industry that offers remarkable opportunity for experimental work for young men to take up this particular field, but in order to do it to their own satisfaction and that of their employer, it is necessary that they should give serious consideration to the labors required of them and the amount of knowledge necessary for them to discharge their duties satisfactorily.

I have made mention of the employment of chemical engineers in the dye-manufacturing plants, but the satisfactory employment of a chemical engineer in the above organic chemical industry resolves itself again into some special branch of chemical work that the engineer has particularly studied.

Broadly, the color industry is divided into the production of: Raw materials, intermediates, dye making. Any one of these sub-divisions is likely to include one or more of the following operations, each of which is generally complex and which should have the undivided attention of the engineer.

I refer particularly to alkali fusions which are generally preliminary operations.

Sulphonation, which involves the use of either artificial or fuming acids.

Nitration and Liming.—These are operations in which sulphonations are generally decomposed.

Filtration.—Where solids are separated from liquids or *vice* *versa.* This is an art. It seems simple at first glance to have a solution with insoluble matter suspended in it or a sludge of greater or lesser density requiring filtration, but it is at its best a problem requiring a great deal of thought, time and attention to be able to successfully filter a given liquid from a solid or a solid from a liquid. There are so many conditions of density, that only long experience can point the way successfully.

It is to be regretted that more young men in our chemical engineering courses have not devoted more time and attention to this particular branch of chemical engineering. Little has been published upon it and the information that has been gained by those who have worked upon filtering problems is generally not divulged.

Drying is another chemical engineering subject that is of the utmost importance, since it occurs so frequently in many phases of dye making, from raw materials to finished dyes. I may mention particularly the production of certain of the Amidonaphthol sulphonic acids and disulphonic acids where both the filtering and the drying determine almost exclusively the value of the finished product. Some of those products depend more upon the skill of the engineer than upon the skill of the chemist.

I could name in succession a number of other important operations, all of which contribute to the successful production of the finished article, and each of which requires that the man in charge—the directing genius—if I may use that term, should be equipped and trained to take care of that particular phase of the work.

Referring again to the amidonaphthol sulphonic acids, I may mention that with the exception of one plant—and that one located in France—no single chemist has been able to successfully carry out every single operation from the conversion of the naphthalene in the first instance to the grinding and sieving of the finished product. This may appear to be a strong statement, but if we consider that to produce these finished products almost every operation previously referred to is involved, it is safe to say that no one industrial chemist or chemical engineer is sufficiently familiar with the innermost details to permit him to successfully direct the work upon every stage in the chain of processes.

Bullet Versus Armor. E. C. CROSSMAN. (*Scientific American*, vol. 118, No. 22, p. 498, June 1, 1918.)—Special armor-piercing bullets were not new when war broke out, but the occasion for them had been limited to getting through the shields of field artillery, and infantry didn't often get close enough to field guns to make this need an urgent one. But after the first year of the war, when snipers began to ensconce themselves behind armor shields and armored cars began to reinforce infantry at threatened points of the line, while airplanes demonstrated surprising immunity to machine-gun fire, the ordnance experts began to take a keener interest in bullets that would not be so easily discouraged on meeting a stubborn steel plate. The most successful armor-piercing bullet yet evolved in this country is that designed by Capt. W. L. Clay of our Ordnance Department, and made at Lowell, Mass., under the supervision of Captain Doe, formerly of our army. This bullet (patent number 1202162), in common with most armor-piercing bullets, uses the hardened steel core within a lead and cupro-nickel outer coating. It differs from any other bullet in that it is closed at the rear and filled from the front end of the jacket, giving higher penetration because of the lessened stripping tendency of jacket and lead. Also it has a softer nose than the tough cupro-nickel jacket. This enables it to bite on hardened steel surfaces very much inclined to its path instead of merely glancing off, as does the service bullet with its sharp nose and long shoulder.

The accuracy of the Clay bullet, while slightly below that of the service bullet, is higher than that of the regular French model, and ample for war use. At 200 yards it makes groups of about eight inches for ten shots, and at 1000 yards it develops some 10 per cent. of fliers, but not enough inaccuracy in the remainder to make its shooting inferior to the regular ammunition from a practical standpoint. The penetration at the muzzle is ¼ to ⅜ inch hardened steel, on which the service bullet merely spattered; at 400 yards it got through ¼ inch, though this was possibly not quite up to Government quality. The trials demonstrated that the making of steel for this light armor, is in itself an uncertain operation. One piece, ¼ inch thick and glass hard, shattered to bits under the bullet's blow. On such steel as this the service bullet does not even offer to go through, merely putting a wide and very shallow dent in the plate; it gives just a blow, without drilling tendency. This is true even on the light $^1/_5$ inch field-gun armor. At 700 yards a service bullet merely dents a ⅜ inch boiler plate, while a Clay slug goes entirely through.

PHYSICS OF THE AIR.*

BY

W. J. HUMPHREYS.

Professor of Meteorological Physics, United States Weather Bureau.

Chapter XIV (*Continued*).

Fig. 109, copied by permission from one of Walter's unpublished negatives, shows the ordinary tracery of a lightning discharge when photographed with a stationary camera. It is only a permanent record of the appearance of the lightning to the unaided eye. Fig 110, however, also copied by Walter's kind permission from one of his unpublished photographs, is a record of the same discharge obtained with a rotating camera. It will be noted that the more nearly vertical discharge occurred but once or was single; that this discharge was quickly followed by a second along the same path to about one-fourth of the way to the earth, where it branched off on a new course; that the second discharge was followed in turn at short but irregular intervals by a whole series of sequent discharges; that most of the discharges appeared as narrow intensely luminous streaks, and that one of the sequent discharges appeared, not to the eye, but on the plate of the rotating camera, as a broad band or ribbon. On close inspection it will be obvious that the plaid-like ribbon effect is due, the warp to irregularities in the more or less continuous discharge, and the woof to roughly end-on and therefore brighter portions of the streak. Another point particularly worthy of attention is the fact that while the first and second discharges have several side branches the following ones remain entire from end to end and are nowhere subdivided.

Fig. 108, taken from a photograph obtained by Mr. Larsen, of Chicago, and kindly lent for use here by the Smithsonian Institution, shows another series of sequent discharges similar to those of Fig. 110, except that in this case there was no ribbon discharge. The time of the whole discharge, as calculated by Mr. Larsen, was 0.315 second. Here, too, side branches occur with the first but only the first discharge. This, however, is not an invariable rule for occasionally, as illustrated by Fig. 111,

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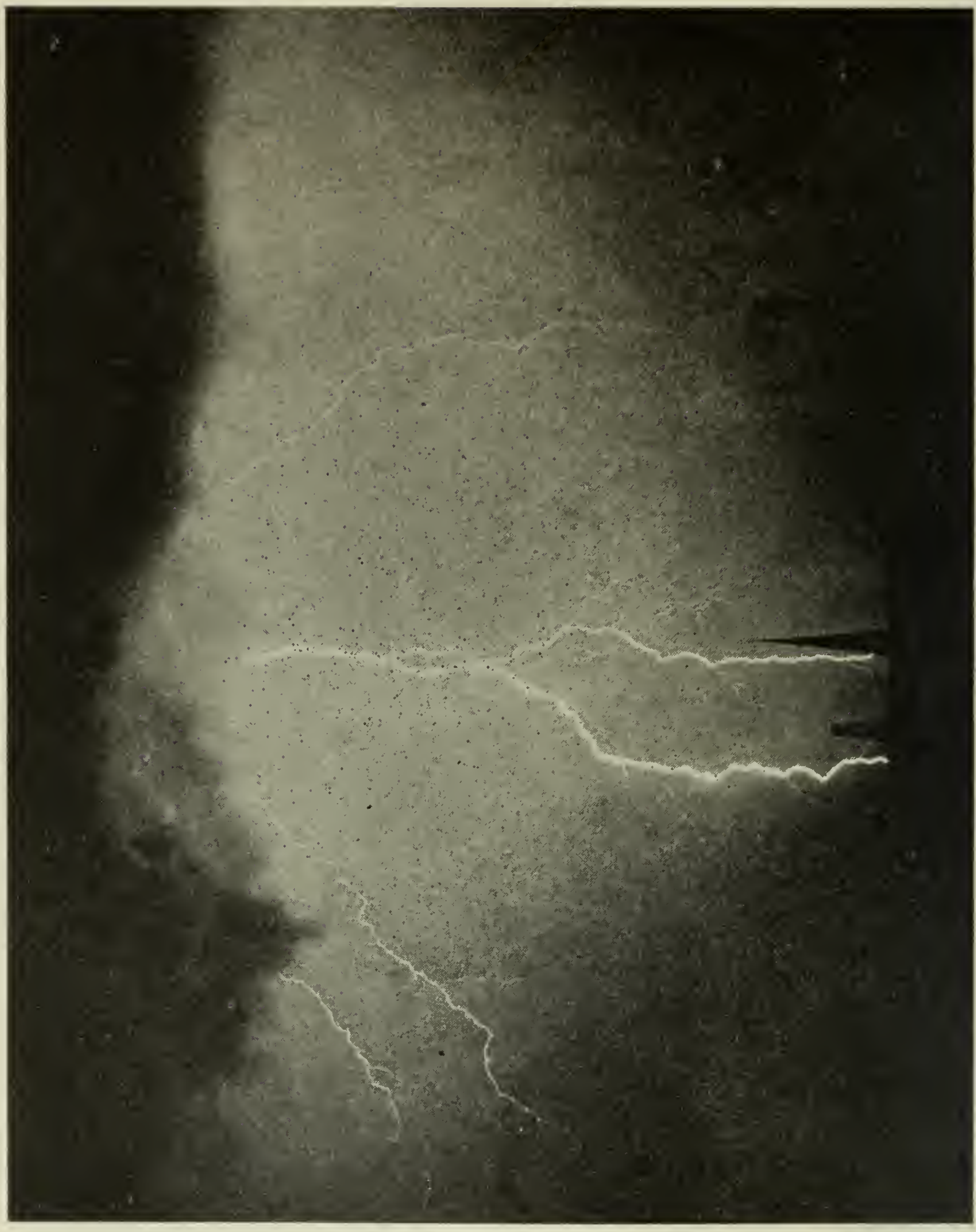
* Continued from page 75, vol. 186, July, 1918.

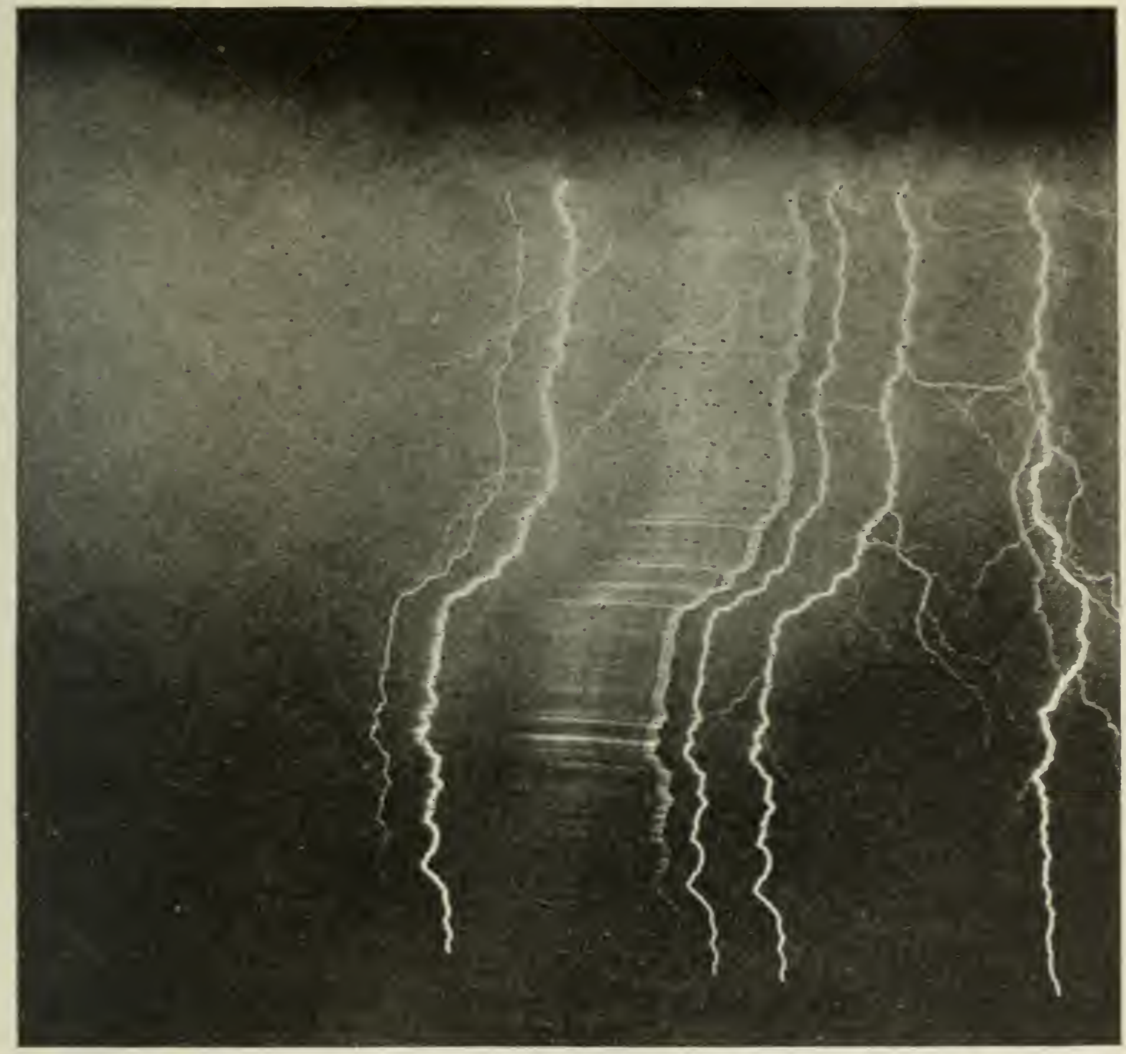
FIG. 109.



Streak lightning, stationary camera; companion to Fig. 110. (Walter.)

copied from a published photograph by Walter, the side branches persist through two or three of the first successive discharges, but not through all. In such case each tributary when repeated follows, as does the main stream, its own original channel.

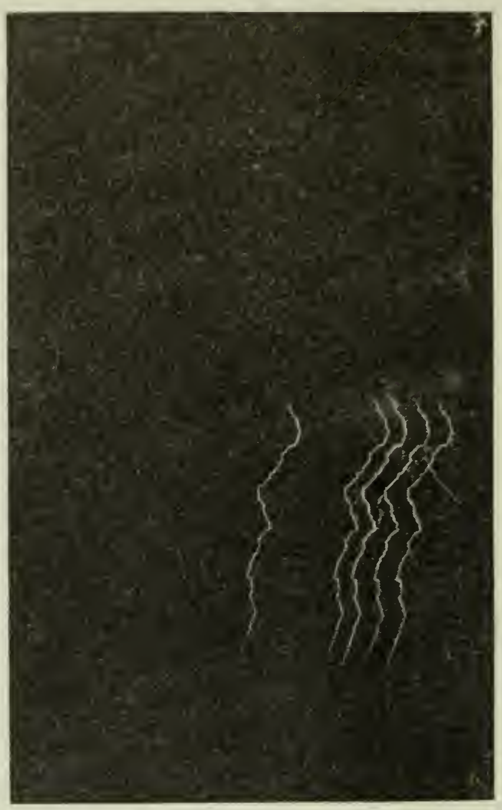
FIG. 110.



Streak lightning (sequent discharges), rotating camera; companion to Fig. 109. (Walter.)

The phenomenon of sequent discharges, all along the same path, and the disappearance of the side branches with or quickly after the first discharge both seem reasonably clear. The first discharge, however produced, obviously takes place against very great resistance, and therefore under conditions the most favorable for the occurrence of side branches, or ramifications. But the discharge itself leaves the air along its path temporarily highly ionized, puts a temporary line conductor with here and there a poorer conducting branch, in the atmosphere. This conductor is not only temporary (half the ions are reunited in about 0.15 second, the air being dusty[97]) but also so extremely fragile as to be liable to rupture by the violent disturbances, both explosive and of other types to be discussed later, it itself creates in the atmosphere. Because partly, perhaps, of just such interruptions, and because also of the volume distribution of the electricity which prevents a sudden and complete discharge, the actual discharge is divided into a number of partials that occur sequently. Obviously the breaks in the conducting (ionized) path, if they exist, are only here and there and but little more than sufficient to interrupt the flow. Hence the next discharge, if it occurs quickly, must follow the conducting and, therefore, original discharge path. Besides, in the subsequent discharges the original side branches

FIG. 111.



Streak lightning (sequent discharges), rotating camera. (Walter.)

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[97] Rutherford, *Philosophical Magazine* 44, p. 430, 1897.

will be quickly abandoned because of their greater resistance, or, what comes to the same thing, because of the more abundant ionization and consequent higher conductivity of the path of heaviest discharge.

This leaves to be explained the genesis of the initial discharge, the least understood perhaps of all the many thunderstorm phenomena. Judging from the voltages required to produce laboratory sparks, roughly 30,000 volts per centimeter, it is not obvious how such tremendous potential differences can be established between clouds or between a cloud and the earth as would seem to be necessary to produce a discharge kilometers in length, as often occurs. Indeed, a fatal objection to the assumption of such high voltage is the effect it would have on the velocity of fall and consequent size of the electrified raindrops. According to Simpson[98], thunderstorm rain often carries as much as 6 electrostatic units of electricity per c.c., and occasionally even more. Hence 30,000 volts per centimeter would produce an electric force on such rain roughly 200 times that due to gravity and therefore either prevent its fall, if directed upward, or, if directed downward, give it a velocity that would quickly break it into fine spray. But thunderstorm rain does not consist essentially of fine spray. On the contrary, as casual observation leads one to believe and as measurements have shown[99], raindrops average larger (1 to 6 mm. in diameter) during a thunderstorm than at any other time. Their velocity of fall therefore can not be excessive, nor indeed does it ever appear to be greatly different from that of ordinary rain. Hence electrical gradients of the order above assumed do not exist between clouds and the earth.

Obviously the potential of individual drops may grow in either of two ways: (*a*) by the union of similarly charged smaller drops into larger ones. In this case, since capacity is directly proportioned to the radius, and the charge, after coalescence, to the volume (if droplets had equal size and charges), the potentials of the resultant drops, that is, their charges divided by their capacities, must be proportional to the squares of their radii, and therefore rapidly increase with coalescence and growth of size: (*b*) by evaporation of however charged drops. Here the charges remain constant and therefore the potential of each individual drop, being inversely proportional to its radius, obviously must become larger as the drop itself evaporates and gets smaller. In each case the tendency of the separate drops to discharge is increased, and the general ionization perhaps somewhat correspondingly increased, but the potential difference between the earth and the cloud as a whole unchanged. At present, therefore, one can do but little more than speculate on the subject of the primary lightning discharge, but even that much may be worth while since it helps one to remember the facts.

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[98] *Loc. cit.*, pp. 149–150.

[99] Bentley, *Monthly Weather Review*, 32, p. 453, 1904.

As already explained the electrical separation within a thunderstorm cloud is such as to place a heavily charged positive layer (lower portion of the cloud) between the earth and a much higher, also heavily charged, negative layer (upper portion of the cloud). Hence the discharges, or lightning, from the intermediate or positively charged layer may be to either the negative portion above, in some cases even an entirely different cloud, or the earth below. Further, through the sustaining influence and turbulence of the uprushing air there must be formed at times and places practically continuous sheets and streams of water, of course heavily charged and at high potential, and also layers and streaks of highly ionized air. That is, electrically speaking, heavily charged conducting sheets and rods, whether of coalesced drops or of ionized air, are over and over, so long as the storm lasts, momentarily placed here and there within the positively charged mass of the storm cloud.

Consider, then, what might be expected as the result of this peculiar disposition of charges and conductors, the result, namely, of the existence of a heavily surface-charged vertical conductor in a strongly volume-charged horizontal layer or region above and below which there are steep potential gradients to negatively charged parallel surfaces.

The conductor will be at the same potential throughout, and therefore the maxima of potential gradients normal to it will be at its ends, where, if these gradients are steep enough, and the longer the conductor the steeper the gradients, brush discharges will take place. Assume, then, that a brush discharge does take place and that there is a supply of electricity flowing into the conductor to make good the loss. The brush and the line of its most vigorous ionization, other things being equal, necessarily will be directed along the steepest potential gradient or directly toward the surface of opposite charge. But this very ionization automatically increases the length of the conductor, for a path of highly ionized air is a conductor, and as the length of the conductor grows so, too, does the steepness of the potential gradient at its forward or terminal end, and as the steepness of this gradient increases the more vigorous the discharge, always assuming an abundant electrical supply. Hence, an electric spark once started within a thunderstorm cloud has a good chance, by making its own conductor as it goes, of geometrically growing into a lightning flash of large dimensions. Of course, when the electrical supply is small the lightning is feeble and soon dissipated.

Whether the discharge actually does burrow its way through the atmosphere in some such manner as that indicated probably would be difficult, though not necessarily impossible, of observation. The gradual lengthening of the streak, if the discharge takes place in this manner, might be detected by photographing it on oppositely directed rapidly moving films. A phenomenon roughly analogous to the burrowing progress suggested[100] can indeed be produced on a photographic plate by bringing in contact with the film, some distance apart, two conducting points attached to the opposite poles of an influence machine. Brush discharges develop about each point, but the glow at the negative pole detaches itself and slowly meanders across the plate toward the positive point. As it goes it continually builds for itself, with the silver of the emulsion, a highly conducting path.

Rocket Lightning.—Many persons have observed what at least seemed to be a progressive growth in the length of a streak of lightning. In some cases[101] this growth or progression has appeared so slow as actually to suggest the flight of a rocket, hence the name.

At first one might well feel disposed to regard the phenomenon in question as illusory, but it has been too definitely described and too frequently observed to justify such summary dismissal. Naturally, in the course of thousands of lightning discharges, many degrees of ionization, availability of electric charge, and slopes of potential gradient are encountered. Ordinarily the growth of the discharge, doubtless, is in a geometric ratio and the progress of its end exceedingly swift, but it seems possible for the conditions to be such that the discharge can barely more than sustain itself, in which case the movement of the flash terminal may, possibly, be relatively slow, and the appearance of a rocket therefore roughly imitated.

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[100] Leduc, *Comptes rendus*, Paris, 1899, **129**, 37.

[101] Everett, *Nature*, London, 1903, **68**, 599.

Ball Lightning.—Curious luminous balls or masses, of which C. de Jans[102] probably has given the fullest account, have time and again been reported among the phenomena observed during a thunderstorm. Most of them appear to have lasted only a second or two and to have been seen at close range, some even passing through a house, but they have also seemed to fall, as would a stone,[103] like a meteor, from the storm cloud, and along the approximate path of both previous and subsequent lightning flashes. Others appeared to start from a cloud and then quickly return, and so on through an endless variety of places and conditions.

Doubtless many reported cases of ball lightning, probably the great majority, are entirely spurious, being either fixed or wandering brush discharges or else nothing other than optical illusions, due, presumably, to persistence of vision. But here, too, as in the case of rocket lightning, the amount and excellence of observational evidence forbid the assumption that all such phenomena are merely subjective. Possibly in some instances, especially those in which it is seen to fall from the clouds, ball lightning may be only extreme cases of rocket lightning, cases in which the discharge for a time just sustains itself. A closely similar idea has been developed in detail by Toepler.[104] It might either disappear wholly and noiselessly, as often reported, or it could, perhaps, suddenly gain in strength and instantly disappear as sometimes observed, with a sharp, abrupt clap of thunder.

To say that all genuine cases of ball lightning, those that are neither brush discharges nor mere optical illusions, are stalled thunderbolts, certainly may sound very strange. But that, indeed, is just what they are, according to the above speculation, a speculation that recognizes no difference in kind between streak, rocket, and ball lightning; only differences in the amounts of ionization, quantities of available electricity and steepness of potential gradients.

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[102] *Ciel et terre,* Bruxelles, 1910, 31, 499.

[103] Violle, *Comptes rendus,* Paris, 1901, 132, 1537.

[104] *Annalen d. Physik,* Leipzig, 1900, 22, 623.

Sheet Lightning.—When a distant thundercloud is observed at night one is quite certain to see in it beautiful illuminations, appearing like great sheets of flame, that usually wander, flicker and glow in exactly the same manner as does streak lightning, often for well-nigh a whole second, and occasionally even longer. In the daytime and in full sunlight the phenomenon when seen at all appears like a sudden sheen that travels and spreads here and there over the surface of the cloud. Certainly in most cases, so far as definitely known in all cases, this is only reflection from the body of the cloud of streak lightning in other and invisible portions. Often a blurred, yellowish steak is seen through the thinner portions of the intervening cloud. Occasionally, too, the cloud is wholly cleared in places where, of course, the discharge is white and dazzling. Conceivably a brush or coronal discharge may take place from the upper surface of a thunderstorm cloud, but one would expect this to be either a faint continuous glow or else a momentary flash coincident with a discharge from the lower portion of the cloud to earth or to some other cloud. But, as already stated, only reflection is definitely known to be the cause of sheet lightning. Coronal effects seem occasionally possible, but that they ever are the cause of the phenomenon in question has never clearly been established and appears very doubtful. It has often been asserted, too, that there is a radical difference between the spectra of streak and sheet lightning, but even this appears never to have been photographically, or otherwise definitely established.

Beaded Lightning.—Many photographs showing streaks of light broken into more or less evenly spaced dashes have been obtained and reported as records of beaded lightning. Without exception, however, these seem certainly to be nothing other than photographs of alternating-current electric lights, taken with the camera in motion. On the other hand, it occasionally happens that a reliable observer reports that he has actually seen a discontinuous or beaded streak of lightning. Thus Professor O. J. Ferguson, of the University of Nebraska (Department of Electric Engineering), says:[105]

"In the spring of 1914 a violent thunderstorm swept over Lincoln at about nine o'clock at night. There were numerous vivid lightning displays. One of these discharges occurring in the storm front originated at an elevation of about 45 degrees from my viewpoint and struck almost vertically downward. I was watching the storm from the window of a dark room, and the flash occurred directly in front of me. It was a direct stroke of chain or streak lightning.

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[105] JOURNAL OF THE FRANKLIN INSTITUTE, V. 179, p. 253, 1915.

" However, in dying away, it took probably a full second to disappear, it broke up seemingly into detached portions, short and numerous. In fact, it gave a bead-like effect, and it would be very easy for one to have retained the latter impression and to have called the stroke bead lightning.

" In explanation of this phenomenon I would suggest that each bead probably represents the 'end-on' view of the irregular portions of the lightning path, and that they remained luminous during the subsequent lesser discharges, while the intermediate sections became non-luminous, because viewed from the side."

The explanation offered by Professor Ferguson and illustrated by Fig. 110 doubtless is entirely correct. Hence beaded or pearl lightning must be accepted as a real though unusual phenomenon, which probably would be more often seen if definitely watched for. Indeed, by close observation, the author has several times had that pleasure.

Return Lightning.—This is commonly referred to as the return shock, and is only that relatively small electrical discharge that takes place here and there from objects on the surface of the earth coincidently with lightning flashes, and as a result of the suddenly changed electrical strain. This discharge is always small in comparison with the main lightning flash, but at times is sufficient to induce explosions, to start fires and even to take life.

Dark Lightning.—When a photographic plate is exposed to a succession of lightning flashes it occasionally happens that one or more of the earlier streak images, on development, exhibits the " Clayden effect "—that is, appears completely reversed—while the others show no such tendency. Obviously, then, on prints from such a negative the reversed streaks must appear as dark lines, and for that reason the lightning flashes that produced them have been called " dark lightning." There is, of course, no such thing as dark lightning, since the only invisible radiation to which the ordinary photographic plate is sensitive is the ultra-violet, which cannot be excited by electric discharges in the atmosphere without at the same time producing visible radiation. Nevertheless, the photographic phenomenon that gives rise to the name "dark lightning," is real, interesting, and reproducible at will in the laboratory.[106]

Duration.—The duration of the lightning discharge is exceedingly variable, ranging from measured intervals of 0.0002 second,[107] and probably less, for a single flash to even a full second or more for a multiple flash consisting of a series of sequent discharges. On rare occasions a discharge of long duration appears *to the eye* to be steady like a glowing solid. Probably the best measurements of the shorter intervals were made by De Blois [108] with the aid of a high-frequency oscillograph. He found the durations of 38 single peaks, averaging 0.00065 second, to range from 0.0002 second to 0.0016 second. Flashes that last as long as a few tenths or even a few hundredths of a second are almost certainly multiple, consisting of a succession of apparently individual discharges occurring at unequal intervals. Occasionally a practically continuous discharge of varying intensity, but all the time strong enough to produce luminosity, will last a few hundredths of a second.

It must be remembered that the duration of even a single discharge and the length of time to complete the circuit, or ionize a path, from cloud to earth, say, are entirely different things. The latter seems usually (rocket and ball lightning may furnish exceptions) to be of exceedingly short duration, while the former depends upon the supply of electricity and the ohmic resistance directly and upon the potential difference inversely.

Length of Streak.—The total length of a streak of lightning varies greatly. Indeed the brush discharge so gradually merges into the spark and the spark into an unmistakable thunderbolt that it is not possible sharply to distinguish between them, nor, therefore, to set a minimum limit to the length of a lightning path. When the discharge is from cloud to earth the length of the path is seldom more than 2 to 3 kilometers; in the case of low-lying clouds even much less, especially when they envelop a mountain peak.

On the other hand, when the discharge is from cloud to cloud the path generally is far more tortuous and its total length much greater, amounting at times to 10, 15, and even 20 kilometers.

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[106] Wood, *Science*, New York (N.S.), 1899, **10**, 717.

[107] De Blois.

[108] *Loc cit.*

Discharge, Where to Where?—As already explained, lightning discharges may be between cloud and earth, between one part and another of the same cloud, or between cloud and cloud. But since the great amount of electrical separation, without which the lightning could not occur, takes place within the rain cloud, it follows that this is also likely to be the seat of the steepest potential gradients. Hence it would appear that lightning must occur most frequently between the lower and the upper portions of the same cloud, and this is fully supported by observations. The next in frequency, especially in mountainous regions, is the discharge between cloud (lower portion) and earth and the least frequent of all, ordinarily, those that take place between one and another entirely independent or disconnected clouds.

Since the electricity of the thunderstorm obviously is generated within the cumulus cloud and there mechanically separated into upper and lower layers it may not at first be clear how discharges can take place to earth at all. Of course, there will be some lines of force between the earth and each cloud charge, but these must be relatively few so long as the charges are equal and approximately superimposed and the resulting dielectric strain correspondingly feeble. However, as the upper charge is carried higher, and especially as it is drifted away from the lower by the winds into which it projects, the lines of force between cloud and earth become more and more numerous, and the strain progressively greater until suddenly relieved by the lightning's disruptive flash.

It would seem, therefore, that a marked difference between the wind velocities at the upper and lower storm levels would be especially favorable to frequency of cloud-to-earth discharges. Hence one would infer that heat thunderstorms, since they occur only when the general winds are light, are less dangerous—less likely to be accompanied by cloud-to-earth lightning—than those (presumably every other type) in which the wind velocity increases more rapidly with elevation. And from this one would further infer that tropical thunderstorms, since they commonly belong to the heat variety, are less dangerous than storms of equal electrical intensity of middle and higher latitudes, where the other or cross-current varieties prevail.

Unfortunately data are not at hand by which these deductions may be tested statistically. They are, however, in accord with the general impression [109] that thunderstorms are more dangerous in England than in India.

Discharges Direct, not Alternating.—Years ago some one for some reason or other, or for no reason, made the statement that the lightning flash is alternating and of high frequency, like the discharge of a Leyden jar, and forthwith, despite the fact that all evidence is to the contrary, it became a favorite dogma of the textbook, passed on unquestioned from author to author and handed down inviolate from edition to edition. True, there often are a number of successive discharges in a fraction of a second, as shown by photographs taken with a revolving camera, but these not only are along the same path but also in the same direction. This is obvious from the fact that side branches, whose trend with reference to the main trunk gives the direction of discharge, persisting as in Fig. 111, through two or more partial or sequent discharges, always follow the same paths. It is also proved by the direct evidence of the oscillograph.[110] In the case of each separate discharge also the direction seems constant; it may vary in strength, or pulsate, but, apparently, it does not alternate.

There are several reasons for concluding that lightning discharges, both single and multiple, are direct and not alternating, of which the following cover a wide range and probably are the best:

(*a*) Lightning operates telegraph instruments. If the discharge were alternating it would not do so, unless very heavily damped.

(*b*) At times it reverses the polarity of dynamos. This requires either a direct current or an alternating one so damped as to be quasidirect.

(*c*) The oscillograph[111] shows each surge or pulsation, as well as the whole flash, to be unidirectional.

(*d*) The relative values of the ohmic resistance, the self-induction, and the capacity, in the case of a lightning discharge, appear usually, if not always, to be such as to forbid the possibility of oscillations.

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[109] Symons, *Metrl. Magazine,* **49**, p. 114 and p. 164, 1914.

[110] De Blois, *loc. cit.*

[111] De Blois, *loc cit.*

From the equation of a condenser discharge,

$$L\frac{d^2Q}{dt^2}+R\frac{dQ}{dt}+\frac{Q}{C}=0$$

it may be shown[112] that whenever the product of the capacity by the square of the resistance is greater than four times the self-induction, or, in symbols, that whenever

$$CR^2>4L$$

oscillations are impossible. Undoubtedly all these terms vary greatly in the case of lightning discharges, but R, presumably, is always sufficiently large to maintain the above inequality and therefore absolutely to prevent oscillations.

To illustrate with perhaps a typical case, assume a cloud whose undersurface is circular with a radius of 3 kilometers, and whose height above the ground is 1 kilometer, and let there be a discharge from the centre of the cloud base straight to the earth: Find a probable value for the self-induction and capacity, and from these the limiting value of the resistance to prevent oscillations, or the value of R in the equation

$$CR^2=4L.$$

To find L we have the fact that the coefficient of self-induction is numerically equal to twice the energy in the magnetic field per unit current in the circuit, and the further fact that per unit volume this energy is numerically equal to $\mu H^2/8\pi$, in which H is the magnetic force and μ the magnetic permeability of the medium. Let a be the radius of the lightning path and assume the current density in it to be uniform. Let b be the equivalent radius of the cylinder, concentric with the lightning path, along which the return or displacement current flows. In this case, μ being unity, the energy W of the magnetic field per unit current and per centimeter length of the discharge is given by the equation

$$W=\log\frac{b}{a}+\tfrac{1}{4}.$$

Let $b=2$ kilometers and $a=5$ centimeters. Then $W=\log_e 4\times10^4+\tfrac{1}{4}=11$, approximately. Hence the energy of the magnetic field per unit current for the whole length, 1 kilometer, of the flash is represented by the equation

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[112] J. J. Thomson, "Elements of Electricity and Magnetism," § Discharge of a Leyden Jar.

$$W 10^5 = 11 \times 10^5,$$

and the self-induction $= 22 \times 10^{-5} = 10^{-4}$ henry.

To find *C*, assume a uniform field between the cloud and the earth. As a matter of fact, this field is not uniform, and the calculated value of *C*, based upon the above assumption, is somewhat less than its actual value, but not greatly less. Assuming, then, a uniform field we have

$$C = \frac{a}{4 \pi d} = \frac{\pi 9 \times 10^{10}}{4 \pi \times 10^5} = 225 \times 10^3 = 25 \times 10^{-8} \text{ farad, about.}$$

Hence, by substitution in the equation

$$CR^2 = 4L,$$

it appears that

$$R = 190 \text{ ohms per kilometer, approximately.}$$

Neither *a*, the radius of the lightning path, nor *b*, the equivalent radius of the return current, is accurately known, but from the obviously large amount of suddenly expanded air necessary to produce the atmospheric disturbances incident to thunder it would seem that 1 centimeter would be the minimum value for *a*. Also, from the size of thunder clouds, it appears that 10 kilometers would be the maximum value for *b*.

The substitution of these extreme values in the above equation gives

$$R = 200 \text{ ohms per kilometer, roughly.}$$

From the fact that *C* varies inversely and *L* directly as the altitude of the cloud it follows that, other things remaining equal, the height of the cloud has no effect on the value of *R* per unit length.

If the altitude is kept constant and the size of the cloud varied *C* will increase directly as the area, and *L* will increase directly as the natural logarithm of the equivalent radius of the cylinder of return current. Assuming the area of the cloud base to be 1 square kilometer, which certainly is far less than the ordinary size, and computing as above it is found that

$$R = 850 \text{ ohms per kilometer, roughly.}$$

Again, assuming the base area to be 1000 square kilometers, an area far in excess of that of the base of an ordinary thunderstorm cloud, the result is

$$R = 35 \text{ ohms per kilometer, roughly.}$$

It would seem, therefore, that a resistance along the lightning path of the order of 200 ohms per kilometer, or 0.002 ohm per centimeter, would suffice, in most cases, absolutely to prevent electrical oscillations between cloud and earth. In reality the total resistance includes, in addition to that upon which the above calculations are based, the resistance in parallel of the numerous feeders or branches within the cloud itself. In other words, the assumption that the resistance of the condenser plates is negligible may not be strictly true in the case of a cloud. Nor is this the only uncertainty, for no one knows what the resistance along the path of even the main discharge actually is; though, judging from the resistance of an oscillatory electric spark,[113] it, presumably, is many times greater than the calculated limiting value; and if so, then lightning flashes, as we have seen, must be unidirectional and not alternating.

Temperature.—What the temperature along the path of a lightning discharge is no one knows, but it obviously is high, since it frequently sets fire to buildings, trees, and many other objects struck. In an ordinary electrical conductor the amount of heat generated in a given time by an electric current is proportional to the product C^2RT, in which C is the strength of the current, R the ohmic resistance, and T the time in question during which C and R are supposed to remain constant. In a spark discharge of the nature of lightning some of the energy produces effects, such as decomposition and ionization, other than mere local heating, but as experiment shows, a great deal of heat is generated, according, so far as we know, to the same laws that obtain for ordinary conductors. Hence extra heavy discharges, like extra large currents, produce excessive heating, and therefore are far more liable than are light ones to set on fire any objects that they may hit.

Visibility.—Just how a lightning discharge renders the atmosphere through which it passes luminous is not definitely known. It must and does make the air path very hot, but no one has yet succeeded, by any amount of ordinary heating, in rendering either oxygen or nitrogen luminous. Hence it seems well-nigh certain that the light of lightning flashes owes its origin to something other than high temperature, probably to internal atomic disturbances induced by the swiftly moving electrons of the discharge, and to ionic recombination.

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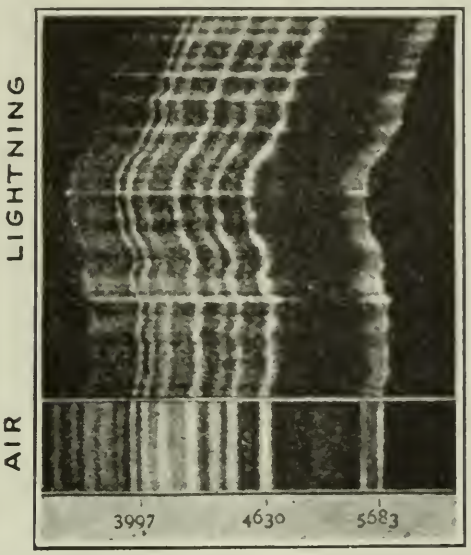
[113] Fleming, "The Principles of Electric Wave Telegraphy and Telephony," 2d ed. 1910, 80, p. 228–237.

Spectrum.—Lightning flashes are of two colors, white, and pink or rose. The rose-colored flashes, when examined in the spectroscope, show several lines due to hydrogen which, of course, is furnished by the decomposition of some of the water along the lightning path. The white flashes, on the other hand, show no hydrogen lines or at most but faint ones. As one might suspect, the spectrum of a lightning flash and that of an ordinary electric spark in air are practically identical. This is well shown by Fig. 112, copied from an article on the spectrum of lightning by Fox,[114] in which the upper or wavy portion is due to the lightning and the lower or straight portion to a laboratory spark in air. Fig. 113 is from an exceptionally fine photograph by Mr. Steadworthy of the Dominion Observatory, Ottawa, Canada. The heavy streak across the spectrum is not the parent, but an accidental stray that got in beside the prism.

FIG. 112.



Spectrum of lightning. (Fox.)

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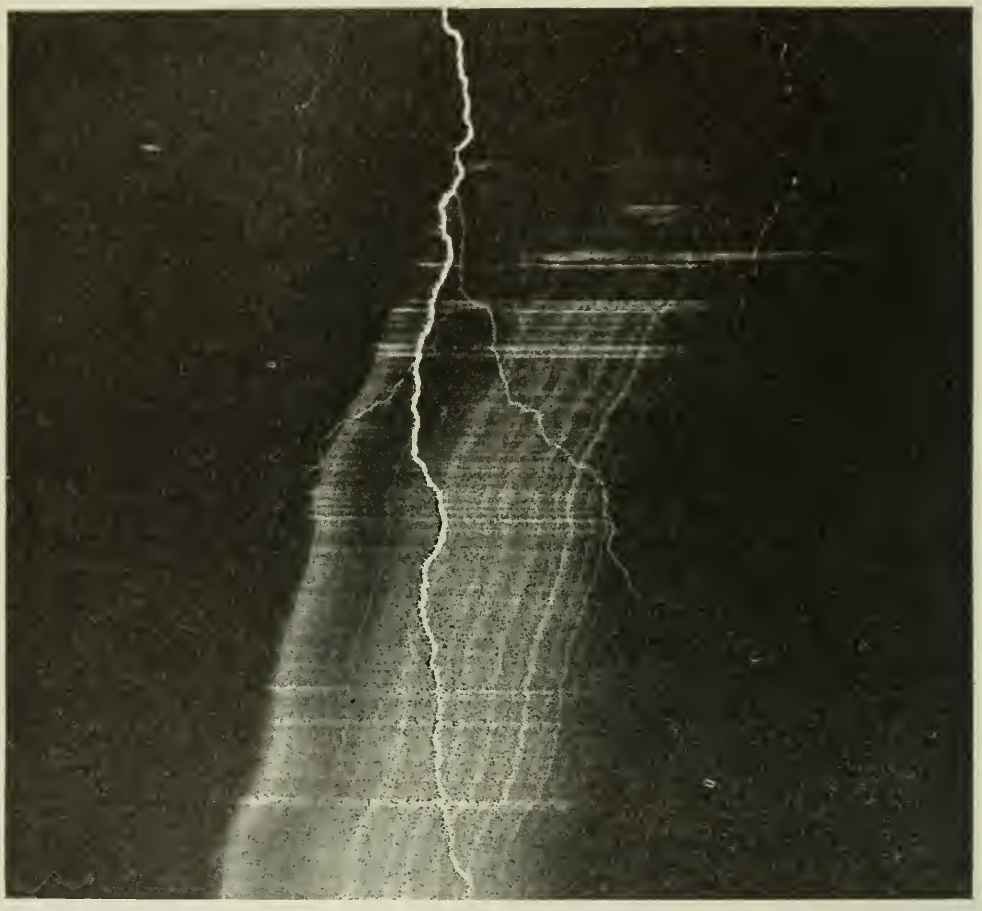
[114] *Astrophysical Jr.*, 1913, 18, p. 293.

It is often asserted that the spectrum of streak lightning consists wholly of bright lines, and that sheet lightning gives only nitrogen bands; and from this it is argued that the latter is not a mere reflection of the first. This assertion is not supported by Figs. 112–113, the brightest portions of which, the portions that would the longest be seen as reflection grew steadily feebler, coincide with strong nitrogen bands.

FIG. 113.



Spectrum of lightning; and stray streak. (Steadworthy.)

Thunder.—For a long while no one had even a remotely satisfactory idea in regard to the cause of thunder, and it is not a rare thing even yet to hear such a childish explanation as that it is the noise caused by the bumping or rubbing of one cloud against another.

Nor are all the learned explanations wholly free from error. Thus it has been suggested that thunder is due to the mutual repulsion of electrons along the path of discharge, though there are several objections to this pleasing hypothesis. If such repulsion really occurred to the extent indicated, one might therefore expect a thread or rod of mercury carrying a current to spread out. Instead, however, it actually draws together, and, with a strong enough current, even pinches itself in two. Again, if mutual repulsion actually drove the electrons violently asunder one would expect the discharge instantly to dissipate, producing some kind of a brush effect, instead of concentrating along the familiar streak. Electronic repulsion, therefore, though it must exist to some extent, does not seem adequate, nor, as we shall see presently, is it necessary, to the production of heavy peals of thunder.

Another plausible but erroneous hypothesis in regard to the origin of thunder insists that it is caused by the collapse of the partial vacuum produced by the heat generated by the lightning. Obviously cooling in this case must be rapid, especially at the instant the discharge ceases, but probably not nearly rapid enough to create sound, nor, therefore, ever to produce any of the crashes and rumbling that always follow heavy lightning.

On the other hand, the heating of the atmosphere, the molecular agitation due to ionization, along the discharge path is so great and the resulting expansion so sudden as to simulate a violent explosion and therefore to send out a steep compression wave. Indeed, compression waves generated by electric sparks are so sharply defined that not only they themselves but even their reflections may be clearly photographed.[115] A compression wave, therefore, generated in the manner just explained, apparently is an adequate cause of thunder, and hence, presumably, its only cause.

Rumbling.—Probably the most distinctive characteristic of thunder is its long-continued rumbling and great variation in intensity. Several factors contribute to this peculiarity, among them:

(*a*) Inequalities in the distances from the observer to the various portions of the lightning's path. Hence the sound, which ordinarily travels about 330 meters per second in the air, will not all reach him simultaneously, but continuously over an appreciable interval of time.

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[115] Wood, *Philosophical Magazine*, 48, 218. 1899.

(*b*) Crookedness of path. Because of this condition it often happens that sections of the path here and there are, each through its length, at nearly the same distance from the observer or follow roughly the circumferences of circles of which he is the centre, while other portions are directed more or less radially from him. This would account for, and doubtless in a measure is the correct explanation of, some of the loud booming effects or crashes that accompany thunder.

(*c*) Succession of discharges. When, as often happens, several discharges follow each other in rapid succession there is every opportunity for all sorts of irregular mutual interference and reinforcement of the compression waves or sound impulses they send out. Occasionally they may even give rise to a musical note of short duration.

(*d*) Reflection. Under favorable conditions, especially when the lightning is at a considerable distance, the echo from clouds, hills, and other reflecting objects certainly is effective in accentuating and prolonging the noise and rumble of thunder. But the importance of this factor generally is overestimated, for ordinarily the rumble is substantially the same whether over the ocean, on a prairie, or among the mountains.

Distance Heard.—The distance to which thunder can be heard seldom exceeds 25 kilometers, while ordinarily, perhaps, it is not heard more than half so far. To most persons, familiar with the great distances to which the firing of large cannon is still perceptible, the relatively small distances to which thunder is audible is quite a surprise. It should be remembered, however, that both the origin of the sound and often the air itself as a sound conductor are radically different in the two cases. The firing of cannon or any other surface disturbance is heard farthest when the air is still and when, through temperature inversion or otherwise, it is so stratified as in a measure to conserve the sound energy between horizontal planes. Conversely, sound is heard to the least distance when the atmosphere is irregular in respect to either its temperature or moisture distribution, or both, for these conditions favor the production of internal sound reflections and the dissipation of energy. Now the former or favorable conditions occasionally obtain during the production of ordinary noises, including the firing of cannon, but never during a thunderstorm. In fact, the thunderstorm is especially likely to establish the second set of the above conditions, or those least favorable to the far carrying of sound.

Then, too, when a cannon, say, is fired the noise all starts from the same place, the energy is concentrated, while in the case of thunder it is stretched out over the entire length of the lightning path. In the first case the energy is confined to a single shell; in the second it is diffused through an extensive volume. It is these differences in the concentration and the conservation of the energy that cause the cannon to be heard much farther than the heaviest thunder, even though the latter almost certainly produces much the greater total atmospheric disturbance.

The Ceraunograph.—Various instruments, based upon the principles of " wireless " receivers and known as ceraunographs, have been devised for recording the occurrence of lightning discharges, whether close by or so far away as to be invisible and their thunder unheard. Of course, the sensitiveness of the instrument, the distance, and the magnitude of the discharge, all are factors that affect the record, but by keeping the sensitiveness constant, or nearly so, it is possible with an instrument of this kind to estimate the approximate distance, progress, and to some extent even the direction and intensity of the storm. Nevertheless, there does not appear to be much demand for this information, and therefore at present the ceraunograph is but sparingly used.

Chemical Effects.—As is well known, oxides of nitrogen and even what might be termed the oxide of oxygen, or ozone, are produced along the path of an electric spark in the laboratory. Therefore, one might expect an abundant formation during a thunderstorm of these same compounds. And this is exactly what does occur, as observation conclusively shows. It seems probable, too, that some ammonia must also be formed in this way, the hydrogen being supplied by the decomposition of raindrops and water vapor.

In the presence of water or water vapor these several compounds undergo important changes or combinations. The nitrogen peroxide (most stable of the oxides of nitrogen) combines with water to produce both nitric and nitrous acids; the ozone with water gives hydrogen peroxide and sets free oxygen; and the ammonia in the main merely dissolves, but probably also to some extent forms caustic ammonia.

Symbolically the reactions seem to be as follows:

$$2NO_2 + H_2O = HNO_3 + HNO_2.$$
$$O_3 + H_2O = H_2O_2 + O_2.$$
$$NH_3 + H_2O = NH_4OH.$$

The ammonia and also both the acids through the production of soluble salts are valuable fertilizers. Hence, wherever the thunderstorm is frequent and severe, especially, therefore, within the tropics, the chemical actions of the lightning may materially add, as has recently been shown,[116] to the fertility of the soil and the growth of crops.

Explosive Effects.—As already explained, the excessive and abrupt heating caused by the lightning current explosively and greatly expands the column of air through which it passes, thereby shattering chimneys, ripping off shingles, and producing many other similar and surprising results. It also explosively vaporizes such volatile objects as it may hit that have not sufficient conductivity to carry it off. Hence trees are stripped by it of their bark or utterly slivered and demolished through the sudden volatilization of sap and other substances; wire fused and vaporized; holes melted through steeple bells and other large pieces of metal, and a thousand other seeming freaks and vagaries wrought.

Many of the effects of lightning appear at first difficult to explain, but, except the physiological, which, indeed, are but little understood, and probably some of the chemical, nearly all depend upon the sudden and intense heating along its path.

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[116] Capus, Guillaume, *Annales de géographie,* 1914, 23, p. 109.

(*To be continued.*)

A SURFACE HAVING ONLY A SINGLE SIDE.*

BY

CARL HERING, D.Sc.

Member of the Institute.

All the usual surfaces with which we are familiar have two sides; a sheet or shell having no appreciable thickness is representative of the mathematician's surface; one side could be colored differently from the other; mathematicians recognize this two-sided property when they refer to the two normals at a point of a surface as differing only in their algebraic signs. The surface of a sphere must be considered as a shell, therefore having an outer, convex, or positive side, and an inner, concave, or negative side.

It is quite simple, however, to devise a true surface which has only one side, and as this has some very odd and peculiar properties the following description of it may be of interest; and when this surface is better understood perhaps some applications of it may be found. Steinmetz in the *Journal of the American Chemical Society,* May, 1918, p. 733, for instance, showed how this and the Riemann surface, on account of their peculiar properties, can be used for illustrating some of the complicated relations in the periodic system of the chemical elements.

If the two ends of a strip of paper or of a flat ribbon be brought together to form a ring, and a twist of half a turn be given to it before the ends are secured together, such a single sided surface (and with only a single edge) is produced. But this form of it is geometrically quite complex and irregular, because the paper does not bend edgewise, and it therefore does not lend itself well to an analytical investigation; it is doubtless for this reason that it had apparently not received the attention it deserves. In order to study the peculiarities of this odd form of surface, the writer constructed numerous models of what he considers to be the simplest type of the geometrically most regular form of it; this regular form, it seems, had not been investigated analytically before.

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* Communicated by the Author.

Let C, C, Fig. 1, represent a circle shown in perspective. Let a straight line *ab* start from the position 1 in the plane of this circle; let this line be moved as a generatrix along the circle as a directrix and always remain in planes passing through the axis of the circle. Simultaneously with this motion let it revolve around the circle as its axis and at *half* the angular rate of its movement around the circle. Hence, when it has moved 90° around the circle, clockwise, into the position 2, it will be inclined 45°, clockwise, to the plane of the circle; in the position 3 it will be perpendicular to this plane; in the position 4 it will be inclined 135°, and when it arrives at the origin again it will have revolved 180° in its own plane; hence, will coincide with its original position 1, but will be reversed in its direction, as is shown in the nearby dotted position 5.

The surface thus described seems to be the simplest geometrically regular form of this one-sided surface, and as its generation follows a regular law it lends itself to analytical investigation. A carved wooden model of this surface when the generatrix *ab* is of a limited length and much less than the diameter of the circle, is shown in Fig. 2, it being then a ring; it of course also has only a single edge. The white zone in the middle represents the centre-line circle, although distorted somewhat on account of the thickness of the ring required to give it strength.

In Fig. 1, the lines *ab* in positions 2 and 4 are in fact parallel, and they are necessarily so in a model constructed in space, but geometrically the line has in fact revolved 90° around its circular axis in passing from 2 to 4; this will be evident if one imagines oneself moving along with the line and always facing it; hence, for position 4 one is supposed to be looking at it from the rear, or from the reversed side of the paper as though it were transparent. With a solid model, such as Fig. 2, this is readily seen by turning the model in the plane of the circle while following the revolving line. It is, therefore, only apparent and not real that the line does not change its direction in passing from positions 2 to 4 through 3, and that it reverses its direction completely in passing from 4 to 2 through 1.

Geometrically considered the straight line generatrix *ab* is of infinite length, but to study this peculiar surface it is best to first start with that limited portion of it which will form a ring, Fig. 2, which will be the case when the length of the line *ab* (the width of the ring) is considerably less than twice the diameter of the circular directrix; this line must necessarily extend equally to both sides of the circle, or else no continuous and uniform ring will be formed.

If such a ring were made of a dielectric and completely covered to near the edge with tin foil, it would not act as an electrical condenser. If an ordinary surface be characterized as bipolar because it has two sides which are algebraically or geometrically of an opposite nature, the present surface would need to be called non-polar. This is its chief peculiar characteristic and places it in an entirely different class of surfaces. For instance, a pin stuck vertically through such a surface would at first seem to represent two normals of opposite sign at the same point; but as the apparently two sides are really one, the pin in fact constitutes two normals at two different points on the *same* side of the surface, which two points coincide in space; relatively to the surface these two normals are like the two outward extensions of a diameter of a spherical shell, and as the two latter may be said to have the same polarity with reference to the shell (if this term may be used as meaning the same direction

FIG. 1.

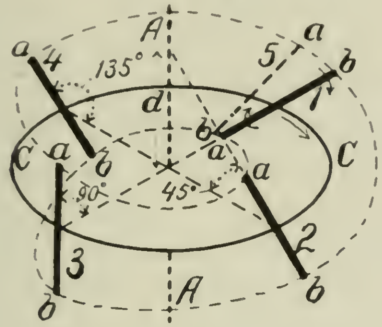


FIG 2.

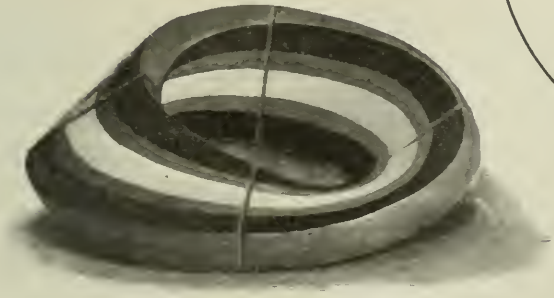
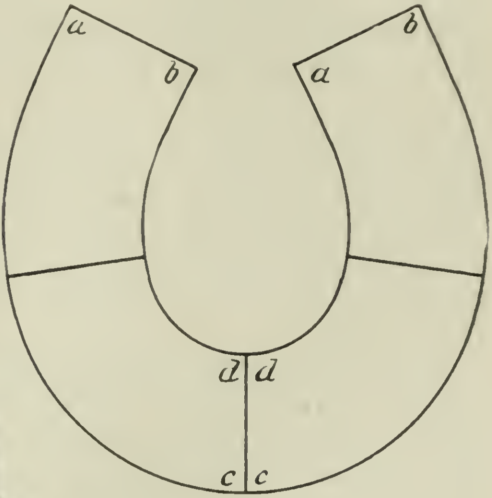


FIG. 3.



relatively to the surface, and from the same side of a surface), then the two normals represented by the pin through this ring also have the same polarity, in which respect they differ radically from the two normals represented by a pin stuck through a spherical shell, the two parts of which would have opposite polarities. The present surface simply has no "other side" and is therefore radically different from the usual ones; if one were to paint one complete side of such a ring one would find that there was no unpainted side left.

If such a ring when made of something flexible, like paper, be cut along the centre-line circle, it will form only one ring of double the diameter.[1] This large ring has then lost the characteristics of this surface, as it has two sides like the usual surfaces; it has four half twists instead of one. Hence, if the present ring, Fig. 2, were covered with tin foil and the foil be cut along the centre-line circle, it would act as a condenser. Or if the ring be colored on the half to only one side of the centre-line circle and then cut as before, it would form a ring which is colored on one side and white on the other. Merely cutting this surface along its centre-line circle, therefore, puts it into the same class as the usual surfaces.

If such a ring be made of paper it could be given any number of half twists before joining the ends. All those in which the number of half twists is an odd one belong to this class; those with an even number belong to the usual class of surfaces. When given three half twists and then cut as before the double-size ring will be found to have a regular knot tied into it. Instead of using a line *ab* as the generatrix it may be a regular polygon, like a triangle, square, etc., and the twists may then be in thirds, quarters, etc.; this, however, leads to solids as distinguished from surfaces.

Mechanically the centre of gravity of such a ring (considered now as having an appreciable thickness) is at its geometric centre; hence, when revolved around its axis it will be perfectly balanced statically. When thus revolved, it forms an excellent model for showing the characteristic motions in a vortex ring. It is statically balanced also around position 1 as an axis.

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[1] This and other features of popular interest were described by the writer in an article on "A Flat Band With Only One Surface and One Edge"; in the *Scientific American*, Feb. 21, 1914, page 156.

Cut in two along an axial plane through the original position 1 in Fig. 1, the two halves are identical in shape; also when cut in two by a plane through the original position and perpendicular to the axis. To make such a ring accurately and without internal strains, it is best to start with a tore (a circular ring of circular cross section), mark off on its surface where the edges will be (according to the law explained in connection with Fig. 1), and then cut away the material down to those lines. A fairly close approximation may be made far more simply from paper, cardboard or sheet metal, by cutting it to the horse-shoe shape, as in Fig. 3 (the approximate development of this surface), and bringing the edges together, *a* to *a* and *b* to *b*. There are, of course, two possible directions of the twist, a right and a left. The ring may also be conceived to be formed of a straight helix (like the usual twist drill) with a half twist, and then bent around to make its axis a circle.

Such rings are only limited portions of this surface in the form of zones. In order to obtain an idea of this surface when extended to infinity the writer made the wire model shown in different positions in Figs. 4, 5, 6 and 7. Beyond the limits of these wires, to infinity, there is nothing of interest, as all the geometric contortions which this surface must go through in order to have only one side are within and near the circular directrix. The sixteen regularly spaced straight wires are all of the same length and are bisected by the circular directrix; the solid ring is merely to hold them in position. In all of them the four chief or cardinal positions of the straight line generatrix are numbered as in Fig. 1; *A* is the axis.

Fig. 4 is nearly in line with the original position 1, and shows the tangential axis *A*. Fig. 5 is about a quarter turn from the former and is nearly in line with the plane of the position 2; it shows the parallelism of positions 2 and 4, and with the intersection *S*. Fig. 6 is about a half turn from position 1 and therefore nearly in line with position 3; it shows the intersecting line *S*. Fig. 7 is approximately from the top, and shows chiefly the edges of the zones of various widths.

The three cords stretched between the wires show the shapes of limited portions or zones like the ring in Fig. 2, extending equal distances to both sides of the circle. The width of the outer zone *O* is nearly four times the diameter of the circular directrix; it shows the general shape of the surface as it passes out to infinity after having gone through its contortions. It will be seen from the top view, Fig. 7, that the edge makes three turns of 360° in completing its circuit; it intersects the axis twice and the intersection *S* four times. The width of the next smaller band *2D* is twice the diameter of the circle; hence, it intersects that circle; its edge again makes three turns to complete its circuit and also intersects the axis twice; it intersects the intersection *S* only twice and is tangent to it once.

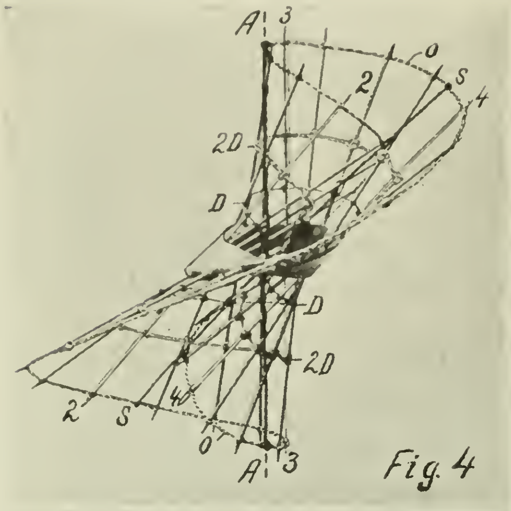

Fig. 4

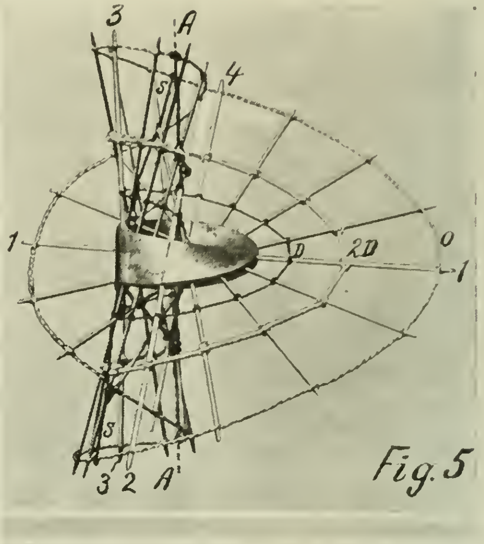

Fig. 5

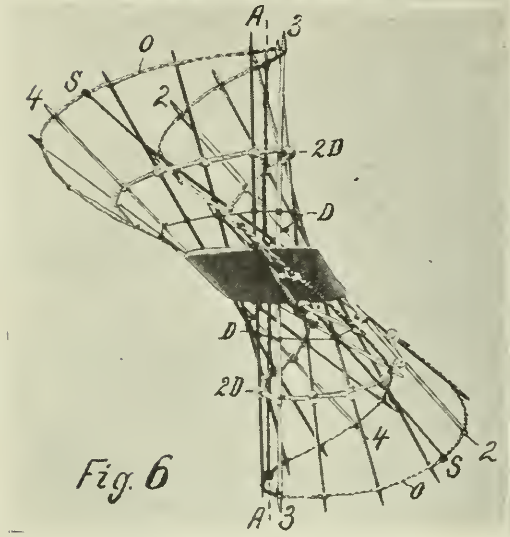

Fig. 6

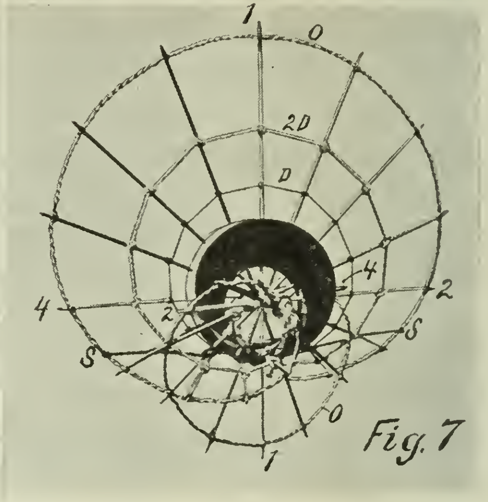

Fig. 7

The width of the next one, *D*, is equal to the diameter of the circle; hence, it meets the axis only once and at this point the axis is tangent to the edge of the ring; it intersects the intersection *S* twice; this and all smaller ones make only two turns of 360° to complete their circuits, the third loop now having contracted into the point of tangency with the axis. In this one the part of the surface which is near the axis is for a short distance practically in an axial plane, and it is the only ring in which this is the case. Mechanically this one is of interest as it can be secured at this tangential edge to a shaft for revolving it, hence without the spokes required for the smaller ones.

Rings of less width than the diameter of the circle are all like the solid ring in the model, that is, like Fig. 2, whose width is a little less than half the diameter; as in the case of ring *D*, their edges make only two turns in the complete circuit; they do not intersect the axis at all, but intersect the intersection *S* twice. The limiting ring is, of course, the circular directrix itself.

The axis *A* is throughout its whole length tangent to the surface, as every position of the generatrix, of course, intersects it. This is of interest in that it shows that this much-curved surface has a second straight line element besides the generatrix. This feature enables this surface to be defined algebraically as one generated by a right line, *ab*, Fig. 1, intersecting the axis, *A*, at different angles and revolving around it so that the axial distance, *d* (shown for position 2), from the normal position 1 is always equal to the tangent of half the angle, *c*, of revolution of its plane from that of the normal position 1; and the angle it makes with the axis is always the complement of the angle $\frac{1}{2}c$. This way of defining it eliminates the circular directrix and shows it to be related to helical surfaces.

This surface must necessarily intersect itself when its width (measured in the axial planes) is greater than twice the diameter of the circle. A curious feature is that the self-intersection of this much-curved surface seems on the model to be a straight line, *S*, making an angle of 45° with the plane of the circle, and lying in a plane tangent to it and perpendicular to the original position 1 of the generatrix. Hence, this surface contains three parallel lines, positions 2, 4, and this intersection *S*; the latter is equally distant from the other two, and the two planes through it and each of the other two are at right angles to each other.

As every position of the right line generatrix must intersect this line of intersection *S* and also the axis, it follows that this surface may also be defined as one generated by a right line generatrix always intersecting two other non-intersecting right line directrixes, each of which makes an angle of 45° with the plane of the other and the normal between them; and that it advances along these lines at certain different trigonometric rates. This also eliminates the circular directrix and shows the surface to be related to warped surfaces. There appear to be no other right lines on this surface than those described.

If it is true that the self intersection S is a straight line, then it follows that this surface can also be defined as one generated by a right line which is moved so as to always be in contact with two other right lines and a circle, one of which lines is the axis

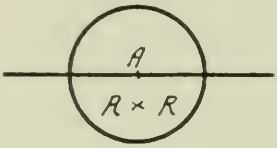

Fig. 8

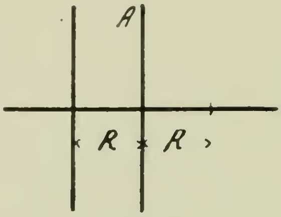

Fig. 9

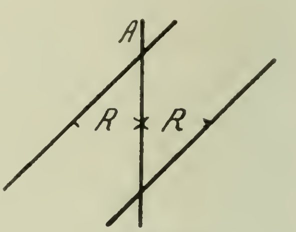

Fig. 10

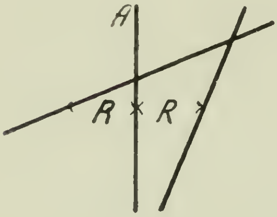

Fig. 11

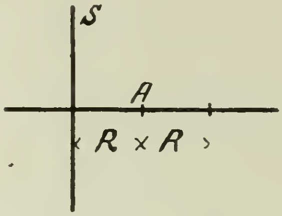

Fig. 12

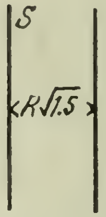

Fig. 13

of the circle and the other is inclined 45° to the plane of the circle and lying in a plane tangential to the circle. This way of defining it eliminates all angles and trigonometric functions.

Another odd feature is that the unlimited surface has two trumpet-shaped, clear, passages through it which are completely separated from each other, such that one liquid might be passed through one of them and another through the other without mixing. This might at first appear inconsistent with the statement made above concerning the condenser action, as these two liquids could now act as the two poles of a condenser. From the model, however, it is readily seen that the formation of these two passages is due to the fact that the surface intersects itself.

The principal cross sections of this surface are shown in Figs. 8 to 13, in all of which R is the radius of the circle, A the axis, and S the line of self-intersection; the right lines, of course, extend to infinity in both directions. Fig. 8 is in the plane of the circle; this seems to be the only section in which there is a perfect circle. Fig. 9 is in the axial plane through the original position 1. Fig. 10 is in the plane of the two 45° positions 2 and 4, Fig. 1. Fig. 11 is in the axial plane half way between those of Figs. 9 and 10. Fig. 12 is in a plane through the line of intersection S and the orginal position 1, and Fig. 13 through this same line S and either of the two 45° positions 2 and 4, Fig. 1; the normal distance between these parallel lines is equal to $\mathrm{R}\sqrt{1.500}$. The sections parallel to the plane of the circle are, of course, all curved loops, each intersecting itself and then passing off to infinity in nearly opposite directions, but they seem to be of no particular interest. The shapes of the edges of the various rings or zones projected on the plane of the circle are seen in the top view, Fig. 7.

When referred to three coördinates, one parallel to the axis, the other parallel to the position 1, and the third perpendicular to both of the others, then the surface is cut three times by every coördinate except the axis itself, which is a tangent throughout, and position 1, which lies entirely on the surface.

In discussing this surface with N. W. Akimoff he evolved the following equation for it, just before going to press:

$$x\left(x^2 + y^2 - r^2\right) + ryz = \pm\left[yz - (x^2 + y^2 - r^2)\right]\sqrt{x^2 + y^2}$$

In this the geometric centre of the surface is at the origin of the coördinates, and the circle whose radius is r, is in the plane of x and y; hence, the axis A in the figures is the axis Z; position 1 lies in the positive direction of x.

Making $x = -r$ gives in the first place y numerically equal to z, which indicates that the self-intersection S is the 45° right line described above; and as another solution $y = 0$, which indicates the straight line 3.

Plentiful Supply of Building Stone and Brick Clays. ANON. (U. S. Geological Survey, *Press Bulletin*, No. 358, March, 1918.)—The large quantities of high-grade granite and valuable brick clays near Richmond, Va., are especially noted in Bulletin 483, published by the United States Geological Survey, Department of the Interior, under the title, "Economic Geology of Richmond, Virginia, and Vicinity." The massive granite that comes to the surface over a large area in the western part of Richmond, says N. H. Darton, the author of the report, is in greater part well suited for use as building stone of the highest grade, and the supply is well-nigh inexhaustible. In recent years Virginia has ranked among the first ten of the granite-producing states, and, though the demand for all building materials has been slackened by the war, the demand for granite and other natural stone will no doubt revive when the country is once more at peace.

The loamy clays in this region are well adapted to use in making building brick, and as they occur in extensive deposits they form the basis of a large industry, Henrico County being the leading one of Virginia in the manufacture of common brick. In 1917 over 43,000,000 brick, valued at $304,000, were made in this county, a considerable increase over the output for 1916.

Mr. Darton found considerable deposits of diatomaceous earth about Richmond, which have so far not been utilized. This earth is used chiefly for cleaning and polishing, either in the form of powder or mixed with soap. It is an effective nonconductor of heat and has been used alone or with other materials as a covering for boilers, steam pipes, and safes and in fireproof cements. It is used largely by paint manufacturers as a wood filler. Boiled with shellac it is made into records for talking machines. It has been used for absorbing liquid manures so that they could be utilized as fertilizers and as a source of silica in making water glass, as well as in the manufacture of cement, tile glazing, artificial stone, ultramarine and other pigments of aniline and alizarine colors, paper filling, sealing wax, fireworks, hard-rubber objects, matches, and papier-maché, and for solidifying bromine.

Teachers of economic and other branches of geology will find this report especially valuable, both for its text and for its numerous clear-cut and instructive illustrations. Bulletin 483 will be sent free on application to the Director of the United States Geological Survey, Washington, D. C.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DETERMINATION OF PERMEABILITY OF BALLOON FABRICS.*

By Junius David Edwards.

The Bureau has published a description of the various methods which may be employed for determining the permeability of balloon fabrics to hydrogen. The precise and rapid method used at the Bureau of Standards measures the hydrogen penetrating a given area of fabric by means of a gas interferometer. Data are given to show the effect upon the apparent permeability of different experimental conditions such as temperature, pressure, humidity of the gas, etc. A knowledge of the effect of these factors enables one to compare results of tests made under different conditions. The test adopted as standard by the Bureau is described.

THE STANDARDIZATION OF THE SAYBOLT UNIVERSAL VISCOSIMETER.[1]

By W. H. Herschel.

[ABSTRACT.]

The Saybolt Universal viscosimeter has always been at a disadvantage, as compared with the Engler instrument, because it has never been standardized with respect to its principal dimensions. To overcome this difficulty the Bureau of Standards entered into negotiations with Mr. George M. Saybolt, and he agreed to accept certain instruments as standard. In some preliminary work with other instruments, it was found that the relation between absolute viscosity and the time of flow could be expressed by the equation.

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00213\ t - 1.535/t \qquad \text{Eq. 1}$$

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* Communicated by the Director.

[1] Technologic Paper No. 112.

where t is the time of flow in seconds, and absolute viscosity and density are expressed in *cgs* units. A similar equation, obtained by using the standard instruments furnished by Mr. Saybolt, was

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00220\ t - 1.80/t \qquad \text{Eq. 3.}$$

Equations of this sort may be used in various ways. If the viscosity and density are known for suitable calibrating liquids, the times of flow, for viscosimeters of normal dimensions, may be calculated from Eq. 2. By comparing these times of flow, with the times obtained by experiment, it may be determined whether or not the instruments at hand are of normal dimensions. These equations also serve as a ready means for finding the time ratio of two different types of viscosimeter. For example, the equation previously found for the Engler instrument No. 2204 U was

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00147\ t - 3.74/t \qquad \text{Eq. 3}$$

By comparing Eqs. 2 and 3 it may be found that when the last terms of the equations are negligible, as they are when the time of flow is greater than about 400 seconds, the time will be 1.50 times as long for a flow of 200 cubic centimeters from the Engler instrument, as for 60 cubic centimeters from the Saybolt instrument. This time ratio increases as the value of t decreases, and for a time, Saybolt, of 36.5 seconds, the time ratio is 1.70.

Results obtained with the Engler viscosimeter are usually reported in Engler degrees, though such results do not, as sometimes supposed, represent relative viscosities. Values in Engler degrees are obtained by the purely arbitrary rule of dividing the time for the liquid tested, by the time for distilled water at 20°C (68 F). The time for water may vary from 50 to 52 seconds, so this value should be used in connection with Eq. 3.

All liquids of known viscosity are not equally suitable for determining the equation of short tube viscosimeters of the usual types. These instruments discharge into the air so that the retarding effect, due to surface tension, is different in different liquids. As these instruments are used mainly for oils, the equations should be found by means of liquids having approximately the same surface tension as oil. Considering the available liquids from this viewpoint, glycerol and sucrose solutions have too high a surface tension, and ethyl alcohol solutions are to be preferred on this account. The surface tension of water is also too high, but water would be excluded on other grounds, even if it were possible to reduce its surface tension without materially changing its viscosity. The viscosity of water is so low that the flow is turbulent, resulting in a change in the constants of formulas like Eqs. 1, 2 and 3.

It has previously been impossible to determine whether a Saybolt Universal Viscosimeter gave normal readings, as neither the dimensions, nor normal times of flow for any given liquids were known. Now that these data have been determined, limit gages have been prepared, and the Bureau of Standards is now in a position to certify whether or nor a given instrument is of standard dimensions.

GROUND CONNECTIONS FOR ELECTRICAL SYSTEMS.*

By Orville S. Peters.

AN investigation of methods of grounding to protect persons from dangers associated with electrical circuits has recently been completed by the Bureau of Standards. The results are to be published in more extended form in a Technologic Paper. The investigation was undertaken in view of the fact that some of the methods of grounding now in use have in many cases proved unsatisfactory, and also that the information heretofore available on the subject is scattered through technical journals and reports and is consequently more or less inaccessible to those most interested in it.

Dangers to persons from electrical systems arise because of the occasional entrance of abnormally high voltage upon the low voltage parts of electrical circuits and equipment, to which persons have access, through faults in insulation between high-voltage and low-voltage circuits. Such faults are developed for the most part by lightning and breakage of wires in storms, and occasionally by high voltage singes or deteriorated insulation.

The magnitude of the potential differences which may appear between low-voltage circuits or parts of equipment and ground is governed by a number of factors, but chiefly by the voltage of the line with which contact is made and the relative location of the point of failure. For instance, with a 2200-volt a.c. distribution circuit feeding a low-voltage lighting circuit through a step-down transformer, a failure of insulation at an end turn of the high voltage winding may raise the potential difference between the lighting circuit and ground to a value approaching 2200 volts unless provision is made with a view to preventing it. A similar condition may arise with any low-voltage circuit if it makes contact with a high-voltage circuit.

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*Technologic Paper No. 108.

Danger from high potentials between low-voltage circuits or parts of equipment and ground can best be averted by grounding the parts affected. For a high degree of safety to life the resistance of the ground connection should be such that with a current flow equal to the rated current of the nearest circuit breaker which will operate to disconnect the equipment or circuit concerned from the source of the dangerous voltage in the event of an accident to insulation, the potential difference between grounded wire and ground will not exceed 150 volts, if the grounded wire, or parts of equipment connected with it, is accessible. If the latter are inaccessible a higher voltage limit is permissible.

Water pipes offer by far the most desirable means of making ground connections, but where it is necessary to resort to other means, such as driven pipes or plates, an appreciable degree of protection can in some places be obtained at reasonable expense. In a great many cases, however, grounds of the latter type will be found unsatisfactory. If a common ground wire is used, a good degree of protection can be had, but the expense may be considerable, and the result not equal to that obtainable from water pipes, unless the common ground wire is connected to a water pipe.

The resistance of water pipe ground connections, where there are no high resistance joints nearby, averages about 0.25 ohm, which is sufficiently low for practical purposes in any case that is likely to arise. The resistance of driven pipe and plate grounds, however, is much higher than that of water pipe grounds. A series of measurements on ground connections made with driven pipes, plates, coils of wire and patented devices showed results as given in the accompanying table. These ground connections were found in service in a number of cities located in different parts of the United States between the Atlantic Coast and the Rocky Mountains.

Resistance by Kinds of Soil.

Number of grounds tested	Soil	Average Resist.	Minimum Resist.	Maximum Resist.
24	Fills, and ground containing more or less refuse, such as ashes, cinders, and brine waste.	14	3.5	41
205	Clay, shale, adobe, gumbo, loam, and slightly sandy loam with no stones or gravel.	24	2.0	98
237	Clay, adobe, gumbo, and loam mixed with varying proportions of sand, gravel and stones.	93	6	800
72	Gravel, sand and stones with little or no clay or loam.	554	35	2700

From these measurements it is readily seen that except in certain localities where natural conditions are particularly favorable towards making ground connections with driven pipes or plates, to obtain a degree of safety equal to that obtained with water pipes would entail an expense that would be almost prohibitive. It is possible, of course, to obtain an appreciable degree of protection with driven pipes in nearly all places, but the comparative advantages in connecting to water pipes are so great that the latter should be used wherever they are available.

Municipalities and water companies are urged to permit the connection of electrical circuits to their water pipes, especially from the point of view of safety to the public. There is, moreover, no possibility of damage to the pipes from currents flowing in them, nor of danger to employees of the pipe owning company, if simple precautions are observed in regard to the use of the pipes for the purpose of grounding.

TESTS OF LARGE BRIDGE COLUMNS.*

By J. H. Griffith and J. G. Bragg.

[ABSTRACT.]

Nature of Investigation.—Tests were made upon eighteen large bridge columns which were half size models of chord sections of railroad bridges recently erected at St. Louis, Mo., Metropolis,

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*Technologic Paper No 101.

Ill., and Memphis, Tenn. The specimens were constructed of nickel, mayari, chrome, silicon and high carbon steels. They varied in length from 15½ feet to 24½ feet, and in cross sectional areas from 42 to 119 sq. in. The slenderness ratios varied from 15 to 44. The columns were of modern design and were constructed in accordance with approved methods of shop practice.

It was the purpose of the investigation to determine the strength of the members as affected by the particular designs and grades of steel used, also the laws of distribution of stress and strain throughout the shafts and details.

Methods of Tests.—The columns were tested in the 10,000,000-lb Olsen compression machine of the Bureau at Pittsburgh. Extensometers of eighty inch gauge length were placed at each corner of the shafts symmetrically with respect to the mid points of the numbers. These were used for the purpose of obtaining data to determine how each column behaved as a unit when subject to stress. Portable Berry gauges of eight and sixteen inch gauge lengths were used to determine the behavior of the details, a large number of observations being made at each 5000 lbs. per sq. in. increments of load.

The data was subsequently used as the basis of determinations of the relative strength of the members, their proportional limits, moduli, deflections and other elastic coefficients. A comparative discussion was given of the data. The laws of behavior were discussed with reference to the designs, types of steel used, independent physical tests of the steels, and compared with similar tests of other investigators.

Results of Observations and Tests.—The strengths of the columns varied from a minimum of 31,200 lbs. per square inch for the carbon steel to a maximum of 65,700 lbs. per square inch for the mayari steel members, the intermediate values corresponding to the grades of steel used in the construction of the columns. The strength for twelve columns failing as units were approximately defined by the yield points of the individual steels used in the construction, being confined within a zone determined by the upper and lower limits obtained by independent tests of the component steels. The mean deviation was found to be one half per cent. from the mean yield points determined for the columns at failure, the range of variation being from 4 to 12 per cent. Of the remaining six columns four failed by local bending at the ends and two by body failures due apparently to the unsymmetrical action of lattice bars.

The mean modulus of elasticity of the columns was found to be 29,000,000 ± 120,000 lbs. per square inch, or approximately that of the component steels. The coefficient of lateral expansion was .30 or approximately that found for steel. The proportional limit of the stress-strain curves of the members was approximately only half that which is found for plain steel. It is believed this reduction was influenced by initial strains from riveting and the built up character of the members.

There was evidence of some lack of integrity of action of the component steel shapes. This was attributed to variations in yield points, a probable breaking down of the frictional resistance between shapes, and the influence of initial strain in the steel from fabrication processes.

The tests to determine the behavior of details showed that there was relative slipping of pin plates at comparatively low loads due to the intensity of the stress just over the pins. It was shown that the lattice without intermediate transverse bars behaved to some extent as a pantograph linkage superposed on the shafts, this causing larger stress in the lattice at the points of constraint near battens and transverse diaphragms than occurred in bodies of the columns. The presence of transverse bars in the Metropolis Bridge columns, it was believed tended to cause a more uniform distribution of stress in the lattice stress. The evidence to support this opinion was found in the fact that the columns having the additional transverse bars always failed in smooth deflection curves, the curves being more or less irregular in those with diagonal lattice alone.

A full discussion was given of the effects of intial eccentricity, the laws of stress distribution from bending of columns, and the laws of distributions in pin plates and lattice. The analyses were conducted from the point of view of the column formula used in design and the more rational formula based on initial eccentricity in a column.

SOME CHARACTERISTICS OF THE MARVIN PYRHELIOMETER.[1]

By Paul D. Foote.

[ABSTRACT.]

The behavior of the Marvin Pyrheliometer has been investigated in detail. The instrument was calibrated by two methods, one in which a known amount of electrical energy was dissipated in the receiver, and the other in which a known amount of radiation from a black body was allowed to fall upon the receiver in the same manner as when the pyrheliometer is employed for solar measurements. The calibration by the two methods agreed within the limits of experimental error. The various constants of the instrument were determined and it was found that the fundamental constant relating the amount of energy received with the rise in temperature of the receiver is independent of the rate of energy supply, at least for an electrical calibration. This fact could not be determined with certainty for a radiometric calibration, because the amount of energy which can be suppled radiometrically from a black body is very small compared to the energy of the solar radiation. The Marvin pyrheliometer calibrated as above was compared by solar observations with the U. S. Weather Bureau Smithsonian standardized pyrheliometer S. J. No. 1, which had been calibrated by comparison with the Smithsonian primary standard water, flow pyrheliometer. The Marvin instrument gave 2 per cent. lower values than the Smithsonian pyrheliometer. This difference is within the errors of observation in the calibration of the Marvin Pyrheliometer by the methods employed above.

Jan. 23, 1918.

INSTRUMENTS AND METHODS OF RADIOMETRY III. THE PHOTOELECTRIC CELL AND OTHER SELECTIVE RADIOMETERS.[2]

By W. W. Coblentz.

During the past ten years investigations have been in progress in this Bureau to determine the characteristics, the comparative sensitivity and the applicability of various types of instruments for measuring radiant energy.

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[1] Scientific Paper No. 323.

[2] Scientific Paper No. 319.

The present paper deals with the application of special physical and chemical properties of matter, as a means of quantitatively measuring radiant energy.

Certain substances have the property of decreasing in electrical resistance when exposed to radiant energy of short wave-lengths; especially the visible and ultra-violet rays. Crystalline selenium belongs to this class of substances, and because of its very marked response to light, its application as a radiometer has been thoroughly investigated by many observers. The sensitivity of the selenium cell varies not only with the wave-length but also with the intensity of the light stimulus; and it recovers but slowly from the effects of the light stimulus. It therefore fails to meet the requirements of a radiometer, except that of high sensitivity.

The application of the photo-chemical action upon a photographic plate, as a means of making quantitative radiometric measurements is considered. While this method of radiometry has been used successfully, its applications seem to be rather limited.

A third application of radiometry, considered in this paper is based upon the fact that some substances, when charged to a negative potential, lose their charge when exposed to light; especially violet and ultra-violet rays. The alkali metals and especially their hydrides, are very sensitive to light stimuli. The photoelectric cells made of these substances can be constructed and operated so that the response (photoelectric current released) is proportional to the intensity of the stimulus. This meets one of the principal requirements of a satisfactory radiometer. Details of construction, operation, and characteristics of the photoelectric cell are given.

A satisfactory, high-resistance, iron-clad Thomson galvanometer is described, which may be used successfully with the photoelectric cell. The advantages of the photoelectric cell over the thermopile are considered and the application of the former is advocated for measurements of radiant energy (especially ratios of intensities) in the violet and ultra-violet parts of the spectrum, where the photoelectric cell greatly exceeds the thermopile and the bolometer in sensitivity.

WASHINGTON, Sept. 10, 1917.

COPPER.[1]

A compilation has been published by the Bureau of the most accurate published information concerning the physical and mechanical properties of the metal copper, together with data and discussion on the effect of higher and lower temperatures upon the physical properties as well as that of impurities in the metal. The circular is concluded with a comprehensive bibliography of the subject, and some typical standard specifications for the metal in different forms.

This circular is one of a series dealing with properties of metals and alloys.

SCOPE AND APPLICATION OF THE NATIONAL ELECTRICAL SAFETY CODE.[2]

[abstract.]

The National Electrical Safety Code consists of four parts and a supplementary section on grounding. The present publication gives a summary of the different parts and points out the need for these safety rules and their present status. This need is illustrated by the citation of one hundred accidents which have occurred from electrical causes.

The method which was used in preparing the Code is described and the reasons given for the form and specific contents of the Code. Instructions are given for finding rules which would apply to any particular installation or situation and the method for making an inspection based upon the Code rules is outlined.

The rules were developed through the coöperation of many engineering and utility associations, engineers, state and municipal officials, electrical workers and others interested in the subject. The rules have already been adopted in certain states and are under consideration in others. Meanwhile they are being tried on a tentative basis by many utility corporations and others to whom they would apply. Manufacturers are greatly modifying their designs so as to conform to the Code rules and all interests are coöperating to secure one standard of electrical construction, installation and operation throughout the country.

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[1] Circular No. 73.

[2] Circular No. 72.

THE FRANKLIN INSTITUTE.

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Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R I

Name and rank	Branch of service	Location
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Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
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Name and rank	Branch of service	Location
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Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
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Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
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Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
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Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
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Cope, Thomas D.	National Research Council	Washington

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Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
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Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
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Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
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Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.

Name	Appointment	Location
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Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R,	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

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NECROLOGY.

Mr. Warner Walter, 1233 Market Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

Alvord, J. W., and Burdick, C. B.—Relief from Floods; The Fundamentals of Flood Prevention. 1918.
Colvin, F. H.—Aircraft Mechanics Handbook. 1918.
Crehore, A. C.—The Mystery of Matter and Energy. 1917.
Cunynghame, H. H.—Time and Clocks. 1906.
Flint, W. R.—Chemistry for Photographers. 1916.
Fryer, P. J., and Weston, F. E.—Technical Handbook of Oils, Fats and Waxes, vol. 1. 1917.
Goldsmith, A. N.—Radio Telephony. 1918.
Hildebrand, J. H.—Principles of Chemistry. 1918.
Mineral Industry.—Vol. 25. 1916.
Peele, Robert, ed.—Mining Engineers' Handbook, 1918.
Photograms of the Year.—Annual Review. 1917–18.
Prideaux, E. B. R.—Theory and Use of Indicators. 1917.

BOOK NOTICES.

The Chemistry of Food and Nutrition. By Henry C. Sherman, Ph.D. New York, The Macmillan Company, 1918. Second edition, rewritten and enlarged, 431 pages, contents and index, illustrations, tables, 12mo. Price, $2.

Dr. Sherman's extended and valuable contributions to our knowledge of food chemistry guarantee that this work will be an acceptable addition to the literature of that subject, and careful reading confirms this. The book contains a large amount of information, clearly and accurately expressed. It is not written as a popular essay, for the statements are mostly presented in the elaborate form and technical language of the well-developed science.

A large amount of statistical information is given in the form of tables. After presenting the general chemistry and nutritive relations of the three main types of food a chapter is devoted to enzymes and digestive processes, then follow detailed discussions of the problems of metabolism and energy requirements. The value of inorganic substances, especially iron compounds, in the diet is considered, after which over one hundred pages are devoted to practical applications of the principles set forth in the earlier part of the work. An appendix on the nomenclature and classification of proteins and one on the composition of foods close the book.

No mention is made of the dietetic relations of the accessory foods. It would have been interesting to hear Dr. Sherman's summary of the existing trustworthy data concerning the effects of alcohol, tea, coffee and cacao, but in a work of this kind the author usually finds it necessary to exclude certain incidental topics.

Notwithstanding the great amount of information in the work, the excellent style in which it is written and the care that has been taken to be accurate and thorough, the reviewer feels that many a thinking reader will close the book with a puzzled feeling. Can the human dietary be reduced to a mere question of calories? One is reminded of the story of the little girl, who, having been fed for a week or so on artificial foods, suddenly sat up in bed and said: "Not another ounce of nourishment will I take. I want my dinner." There are psychic elements in our food-taking that cannot be ignored. It is not, however the duty of the chemist to discuss these, but in the field of food-control and dietetic regulation, the old proverb that one man's meat is another man's poison must not be forgotten. The United States have never had a national food-problem until the present, and it is very important that the scientific data and the psychologic features should be given thorough consideration. Dr. Sherman's book will be a valuable addition to the former phase.

HENRY LEFFMANN.

JAMES WOODHOUSE: A PIONEER IN CHEMISTRY, 1770–1809. By Edgar F. Smith, Provost of the University of Pennsylvania. Philadelphia, The John C. Winston Company, 1918, 299 pages, plates, portrait, 12mo. Price, $1.50.

If it were not for the chapter devoted to his scientific work in Provost Smith's former volume entitled "Chemistry in America," the name of James Woodhouse would scarcely be familiar to the chemists of the present generation. It is nevertheless true, however, that this almost-forgotten Philadelphian was one of the great pioneers of chemistry in America, and one of the bright stars among the galaxy of worthies that made our city the centre of American science a century ago.

In this biography the author presents us with an intimate account of the life and personality of Dr. Woodhouse, as well as a most interesting and appreciative discussion of his scientific efforts and achievements.

The life of this remarkable man of science was singularly free from dramatic incidents, and the main facts of it can be recited very briefly. His parents had come to Philadelphia from England in 1766, and it was in this city that he was born in 1770. And it was in his native city also that he received his elementary education and his scientific training and that he spent practically the whole of his career. He died as Professor of Chemistry and Dean of the Medical School of the University of Pennsylvania in 1809.

His interest and love for the science to which he was to devote his life were awakened in him while he was an undergraduate student in the University, and it was the personality and fame of Doctor Benjamin Rush that attracted him to the Medical School after he had taken the degree of Bachelor of Arts. Before completing his medical course he briefly served as surgeon in the army during an Indian campaign, but he promptly resumed his studies and passed his examinations for the degree of Doctor of Medicine after presenting a rather elaborate thesis on a chemical subject.

After a brief medical career he decided to devote himself to the pursuit of chemistry. To promote chemical research and to disseminate the latest and most valuable information on chemical subjects he founded the Chemical Society of Philadelphia, the first chemical society in the world, of which he was the first and the only president. In this capacity he succeeded in enlisting the coöperation of a large circle of specialists, and in giving much useful instruction and advice to his fellow citizens.

In 1795 he was elected Professor of Chemistry in the Medical School of the University, the Professorship having been declined by Joseph Priestley. The chair had previously been occupied by James Hutchison.

In 1796 Woodhouse was elected a member of the American Philosophical Society, in the affairs of which he was active until his death, serving at various times as secretary and councillor.

By far the most important contributions Woodhouse made to chemical science were between 1795 and 1809, *i.e.*, the period during which he occupied the chair of chemistry in the University. In spite of his limited preparation and equipment he rapidly forged ahead to become the acknowledged leader in his chosen field. Without question his greatest achievement was that he succeeded in establishing both by experiment and by his writings correct ideas on the fundamental processes of chemistry, such as combustion, respiration, the formation and decomposition of water, etc. He combated the erroneous views of Priestley (whom he greatly admired as a discoverer), and of other exponents of the phlogistic theory, and championed the teachings of Lavoisier and the French school.

As an investigator he made many valuable observations and discoveries in vegetable chemistry, and succeeded, independently of Davy and Gay Lussac, in isolating potassium. He also devised numerous methods of chemical analysis which although crude and imperfect compared with those of the present day, have proved of great service in his hands and those of his contemporaries.

Woodhouse was a great believer in the laboratory method of instruction. His biographer is evidently of the opinion that he was one of the first chemists either here or abroad to emphasize the value of direct experimentation, and he calls attention to the fact that "The Young Chemists Pocket Companion," published in 1797, was "in all probability the first published guide in experimentation for chemical students."

No less important than his work as an investigator and teacher were his unremitting and successful efforts to develop and improve industrial chemical processes, and to make the natural resources of his country available for the well-being and prosperity of the inhabitants of the newly born republic.

He was beloved and admired by his students, to not a few of whom he succeeded in imparting his own enthusiasm for research and teaching. And one of these at least—the illustrious Robert Hare—even surpassed his master in these respects.

Such are a few of the outlines and high lights in the picture which Provost Smith has painted for us in the Life of James Woodhouse. To enjoy and appreciate the perspective and warmth of color, as well as the wealth of detail, a careful perusal of this little volume is necessary. It constitutes a most acceptable contribution to our knowledge of the first beginnings in our country of the great science which now counts its votaries by tens of thousands, and which has grown to be an indispensable aid to the nation in both peace and war.

HARRY F. KELLER.

ORGANIC COMPOUNDS OF ARSENIC AND ANTIMONY. By Gilbert T. Morgan. London, Longmans, Green & Co., 1918, 350 pages, contents, introduction, bibliography and index, illustrations, 8vo. Price, $4.80 net.

This work is one of a series of monographs on Industrial Chemistry, each of which is to be under the charge of a specialist, the whole to be editorially supervised by Sir Edward Thorpe, C.B., LL.D., F.R.S. Twenty-eight are enumerated as already planned, of which several, including the present volume, have been issued. It is interesting to note that four volumes are assigned to synthetic colors.

The work under review contains a very large amount of matter, carefully and plainly set forth, and really will astonish the average chemist by the array of organic derivatives that have been produced by the standard synthetic methods. Of course, when such compounds are mentioned, every chemist thinks of the kakodyl derivatives, and one of the most interesting portions of the book is the historical note concerning these, starting with an account of the first preparation of the impure kakodyl oxid, which was long known under the title of "Cadet's Fuming Liquor." The exact nature of the principal constituent of this liquid was ascertained by Bunsen, in a series of researches which Berzelius said, justly, would alone give a name that would live as long as the science of chemistry. It is also generally known to chemists that Bunsen discovered the remarkable fact that while so many of the kakodyl derivatives are highly poisonous, kakodylic acid is a striking exception.

The interest that attaches to the substances described in this work arises from two sources: the antiquity of the earliest production of them, and their powerful and special physiologic effects. Louis Claude Cadet de Gassicourt, a military apothecary, residing in Paris, published in 1760 an account of the experiments which produced the "fuming liquor," the composition of which long remained undetermined. The physiologic effects of arsenical organic derivatives have of late been prominently before the world in connection with "salvarsan" or, as first termed, "606," so much now in favor as an antisyphilitic remedy.

Dr. Morgan's book is a most valuable addition to the chemistry of this important field of synthetic work. It is well-printed and provided with a good index and an extended bibliography. The reviewer is glad to note that the spelling "gram" is used.

HENRY LEFFMANN.

HELVETICA CHIMICA ACTA: Under this title the Swiss Chemical Society has begun the publication of the papers presented to it. The first number, just at hand, is of the ordinary octavo size, with 96 pages of printed matter. The numbers will be issued about every two months. The papers will appear mostly in one of the three languages spoken in Switzerland: French, Italian and German. Among the contributions to the first number may be noted the following that are interesting either by novelty or practical application: Guye and Schneider (in French), "Reduction of Nitrogen Oxides to Ammonia"; Gassmann (in German), "On the Occurrence of Hydrogen Selenid in Rain and Snow"; Pictet and Sarasin (in French) "On the Distillation of Cellulose and Starch under Reduced Pressure."

All of the contributions are of a high scientific character.

Henry Leffmann.

PUBLICATIONS RECEIVED.

Chemistry of Food and Nutrition, by Henry C. Sherman, Ph.D. Second edition, rewritten and enlarged. 454 pages, illustrations, 12mo. New York, The Macmillan Company, 1918. Price, $2.

Organic Compounds of Arsenic and Antimony, by Gilbert T. Morgan, D.Sc. 376 pages, 8vo. London, Longmans, Green & Co., 1918. Price, $4.80.

Edible Oils and Fats, by C. Ainsworth Mitchell, B.A. 159 pages, illustrations, 8vo. London, Longmans, Green & Co., 1918. Price, $2.

University of Illinois, Bulletin: Water Survey Series, No. 14. Chemical and biological survey of the waters of Illinois. Report for the year ending December 31, 1916. Edward Barton, Director. 190 pages, illustrations, 8vo. Urbana, University, 1917.

U. S. Bureau of Standards: Circular No. 73, Copper. 103 pages, illustrations, plates, 8vo. Scientific Paper, No. 321. Thermal expansion of alpha and of beta brass between 0 and 600° C. in relation to the mechanical properties of heterogeneous brasses of the Muntz metal type, by P. D. Merica and L. W. Schad, associate physicists. 19 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

U. S. Bureau of Mines: Bulletin 132, Siliceous Dust in Relation to Pulmonary Disease Among Miners in the Joplin District, Missouri, by Edwin Higgins, A. J. Lanza, F. B. Laney, and George S. Rice. 110 pages, illustrations, plates, 8vo. Bulletin 151, Recovery of Gasoline from Natural Gas by Compression and Refrigeration, by W. P. Dykema. 123 pages, illustrations, plates, 8vo. Bulletin 164, Abstracts of Current Decisions on Mines and Mining Reported from September to December, 1917, by J. W. Thompson. 147 pages, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States, March, 1918. List of permissible explosives, lamps, and motors tested prior to April 30, 1918, compiled by Albert H. Fay. 23 pages, 8vo. Technical Paper 144. The Quick Determination of Incombustible Matter in Coal and Rock-Dust Mixtures in Mines, by A. C. Fieldner, W. A. Selvig and F. D. Osgood. 36 pages, illustrations, plate, 8vo. Technical Paper 172, Effects of Moisture on the Spontaneous Heating of Stored Coal, by S. H. Katz and H. C. Porter. 25 pages, illustrations, plate, 8vo. Technical Paper 185, Use of the Interferometer in Gas Analysis, by Frank M. Seibert and Walter C. Harpster. 18 pages, illustrations, 8vo. Technical Paper 194, Report of the Committee on the Standardization of Mining Statistics, compiled by Albert H. Fay. 39 pages, 8vo. Chart of Properties of

Mine Gases, compiled by G. A. Burrell, 26 by 36 inches. Washington, Government Printing Office, 1917–18.

U. S. Department of Agriculture: Prevent Grain Dust Explosions and Fires. 7 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

U. S. Tariff Commission: Outline of its Work and Plans, 13 pages, 8vo. Tariff Information Series No. 3. Silk and Manufactures of Silk, Schedule L. 163 pages, 8vo. Washington, Government Printing Office 1917–18.

School of Mines and Metallurgy: University of Missouri Bulletin, March 1918. Catalogue 1917–18. 169 pages, illustrations, 8vo. Rolla, Mo., 1918

A Modern Plant for Thawing Coal Cars. S. W. LINN. (*The Railway Age,* vol. 64, No. 13, p. 805, March 29, 1918).—Scarcity of labor and prolonged severely cold weather have much to do with delays in moving materials from producer to consumer, and very little can be done on short notice to offset the retarding effect of either of these conditions. In winter the freezing of materials, like coal, ore. sand, or gravel, which are usually shipped in open-top cars, adds greatly to the cost and delay of their delivery. When these commodities are shipped any considerable distance and are held on cars for several days, they are in a more or less frozen condition, depending on the severity of the weather and the amount of moisture in them.

At tidewater coal shipping ports the handling of frozen coal forms one of the most serious problems in winter operation. It is necessary at most of these ports where coal is unloaded from cars to boats by car dumper that the work be carried on in winter weather at the same rate as in summer. Much of the coast towns' supply of coal depends on shipment from these ports. Various methods for thawing coal in the cars have been used, most of them without great success from an economical operating standpoint. The plan mostly used until about seven years ago was the so-called point system. Thawing was attempted by driving gas pipes into the frozen coal and introducing steam into the coal through these pipes. This was an expensive and awkward method, and was attended by considerable danger to workmen as open to the objection that the coal was left in a saturated condition.

The thawing plants operated by the Eastern Coal Dock Company at its coal-unloading plants at Philadelphia and South Amboy, N. J., the latest of which consists of a concrete building, 570 feet long, with three rooms, each containing one track. Heated air is employed for thawing. The air is carried the full length of the building through ducts and discharged through flues arranged to discharge upwardly toward the bottom of the cars. This plant has a holding capacity of 42 cars, each 40 feet long. Under severe freezing conditions and with the average coal, from one and a half to two hours are required to thaw the coal so that it will unload freely.

CURRENT TOPICS

The Control of Industrial and Scientific Information. W. Rintoul. (*Journal of the Society of Chemical Industry,* vol. 37, No. 4, p. 67R, February 28, 1918).—Among the essentials necessary to success in industrial organization, the collection of information bearing on the industry in question and filing it in available form are of paramount importance. The most difficult duty which falls to the lot of the department devoted to the collection of data is the grading of the information secured into that which is of sufficient importance for record and that which is likely to be of ephemeral interest only. Another difficulty to be faced is the selection of the most readily appreciable method of filing the collected information. Perhaps the best solution of this difficulty is the adoption, as the main guide of filing, of the mechanical form in which the information is presented; that is to say, whether as a book, a periodical, an extract, or patent, a typewritten document, or a manuscript, without any reference whatever to the subject to which the information in question relates. This method of filing posseses the great advantage of compactness, and in most cases the economical use of space available is an important consideration.

Having fixed upon a method of filing, a reliable index becomes a necessity. It is a common impression that no great degree of skill or experience is necessary for the construction of a satisfactory index, but the idea is entirely fallacious. On one occasion some five individuals, all of whom were experts in one or another division of knowledge, but with no great experience in indexing, attempted to construct such an index. After some months of work it was found that so many contradictory decisions had been made that much confusion had already been introduced, and it was realized that in a very few years' time the index would become so complicated as to be unworkable. It was therefore decided to study more carefully the various systems that have been proposed from time to time, with the object of selecting the one best adapted to meet existing conditions. The choice finally lay between that adopted in 1905 by the "Institut International de Bibliographie" of Brussels and that proposed by J. Kaiser in his monograph on "Systematic Indexing," published in 1911. This is a card system in which concrete terms are used as the main guides, followed by sub-guides relating to geographical position and process. The card contains an epitome of the information to be found in the original, followed by a reference which enables the original article to be consulted. The experience gained in constructing and using an index of 150,000 cards during the past five years has led to the opinion that it admirably fulfils the object for which it was designated.

Vitamines. W. RAMSDEN. (*Journal of the Society of Chemical Industry*, vol. 37, No. 4, p. 53T, February 28, 1918).—It has been discovered during the last twenty years that as wide a variety of animals as pigeons, fowls, rats, pigs, and man, if fed exclusively on polished rice, develop the disease known as beri-beri, characterized by serious changes in the peripheral nerves, and that a water or a 90 per cent. alcohol extract of the rice-polishings contains a substance of which very minute quantities prevent or cure the disease. By careful and laborious experiments with rice and other diets it has been shown that this substance is widely spread in the common foodstuffs and that its presence is essential for life. Attempts to isolate it in a pure state in sufficient quantity for chemical investigation have not hitherto been completely successful, but enough has been ascertained to make certain that it is neither a protein, fat, nor carbohydrate, nor inded any of the known constituents of plants or animals. Funk has proposed for it the name "the anti-beri-beri vitamine," and this term "vitamine," although open to many objections, has been widely adopted for substances of this type. The name "sitacoid," meaning a medicine-like substance associated with food, is suggested by the writer as accurately descriptive and not implying a knowledge of their chemical character which we do not possess.

Most foodstuffs contain adequate amounts of the anti-beri-beri substance, but it is important to note that white flour, polished rice, and arrow-root, and probably also "corn-flour," and much of what is sold as tapioca, and semolina contain none. Ordinary white bread probably contains a little derived from its yeast, but certainly not enough for health unless supplemented by other foodstuffs. Wheat-bran contains a little, wheat embryo a considerable quantity. It is present in quantity in yolk of egg, cod-liver oil, and all animal fats investigated (with the remarkable exception of lard), milk, cheese, butter, margarine made from animal fats, green leaves, soya beans, millet, and flaxseed. It is absent from lard and all vegetable oils (almond, maize, cottonseed, sunflower seed, linseed, and soya bean oils) and margarines made from them. It is present, although apparently in small amount only, in the (entire) seed of wheat, oats, maize, rye, and cotton seed.

Methods of Rapid Nickel Plating. ANON. (*The Metal Record and Electroplater*, vol. 4, No. 3, p. 85, March, 1918.)—Nickel plating has been practised for about fifty years, and in all that time, up to the last two or three years, platers have been satisfied with the slow process of electrodeposition of nickel as practised by their fathers before them. That is, they have been content to deposit nickel with the low rate of 3 to 5 ampères per square foot. A few years ago "rapid nickel salts," claimed to permit of nickelling at two or three times the usual rate, were imported from Europe. These proved to be only mixtures capable of yielding more concentrated solutions than that enemy of progress, the double sulphate, which for so long has masqueraded as the plater's friend. The American plater ultimately learned to make up his own rapid solution, and as a result nickelling at 10 to 20 ampères per square foot is very common to-day.

The most recent step in rapid plating is the remarkable work of Kalmus and Barrows in plating with cobalt at 150 ampères per square foot, turning out commercial plating of high grade in three minutes. This achievement with cobalt suggested the desirability of obtaining similar effects with the cheaper nickel solution. In so far as the excellent results of the cobalt solution depend upon its extreme concentration (312 grammes of anhydrous cobalt sulphate per litre), it should be possible to duplicate them with nickel, since its salts are equally soluble. It is, however, in anode corrosion and in its absorption of hydrogen that nickel is inferor to cobalt as a metal for electroplating. The nickel anode becomes "passive" on the slightest provocation, and, instead of all the current dissolving nickel as is desired, a portion of it is spent in producing acid at the anode. Besides cutting down the efficiency of deposition, this acid causes hydrogen to be evolved in considerable quantity on the cathode, where some of it is absorbed by the deposit. Absorption of hydrogen by nickel renders it hard and brittle, and is likely to cause it to curl away from the metal on which it is deposited.

The addition of a small amount of some chloride to the sulphate solution generally employed for nickel plating is a well-known remedy for this passivity of the anode. Previous experience with hot nickel solutions indicates their use for overcoming these difficulties, since in a hot solution anode corrosion is greatly improved and absorption of hydrogen is lessened. A 25-gallon hot nickel bath was used at 125 to 150 ampères per square foot with great satisfaction, producing in five minutes a heavier deposit than is obtained in an hour with the usual rapid bath at 10 ampères per square foot. This solution contains nickel sulphate (single salt), nickel chloride, and boric acid. In spite of the extreme current density, the deposits were superior in quality and adherence to ordinary nickel plate.

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GROWING MEDICINAL PLANTS IN AMERICA.*

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Modern warfare may be roughly divided into two distinct phases: one is destructive and the other reconstructive. There are no longer crucial battles which decide the issue of war as at Waterloo or Gettysburg, but there is instead one protracted and unceasing effort to destroy the enemy's life and property on the largest scale possible. Nevertheless, the reconstructive work must follow the destructive on an equally gigantic scale. Never before in the history of mankind has such organization existed for the first-aid and subsequent treatment of the sick and wounded, and never before has there been such concentrated human and animal suffering calling for alleviation.

It is a curious dispensation of Providence that man first found, and still to a very large extent depends for his remedial and anæsthetic agencies on, the familiar herbs and weeds which grow wild about his woods, fields and hedgerows. The term "drug" includes all substances used as medicines, as well as those substances which may be misused as intoxicants or anæsthetics. Drugs may be mineral, such as the bromides, iodides, and chlorates of potassium, the mercurial, arsenical, and silver compounds and many others. In addition to these, modern medicine depends largely on the coal-tar derivatives, among which may be mentioned some of the more familiar, as, for instance, acetanilid,

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* Presented at the stated meeting of the Institute held Wednesday, April 17, 1918.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

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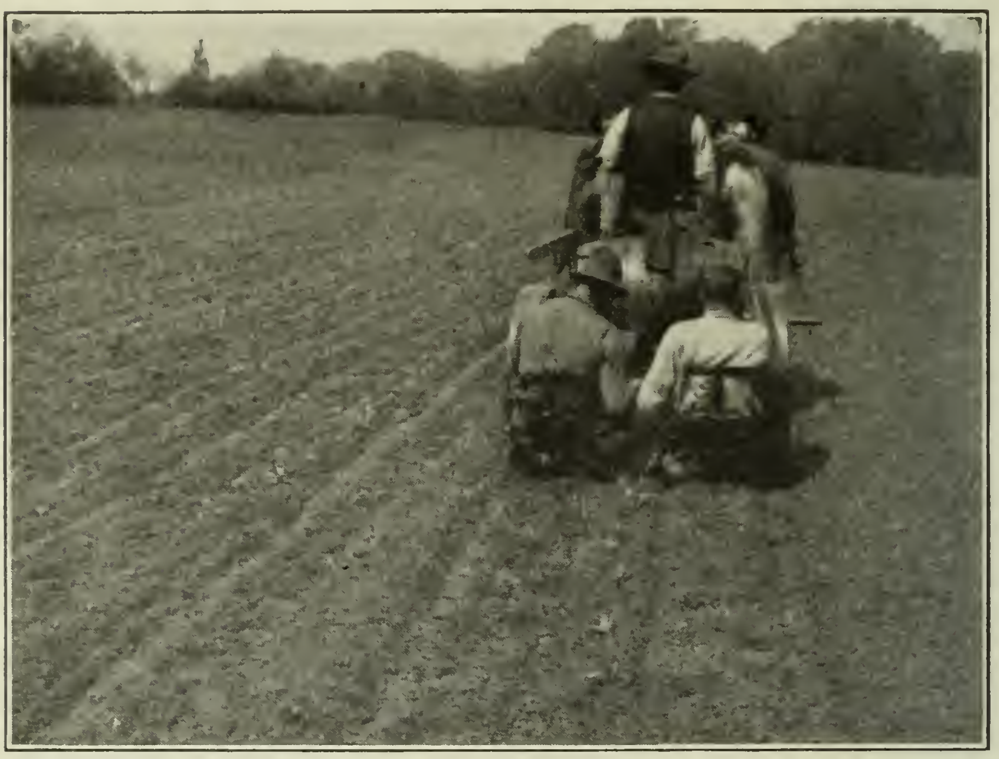
phenacetin, and the various salicylates, under such trade names as aspirin and salol, owned and exploited before the war exclusively by the Germans. The present paper, however, concerns itself particularly with the raw materials from which such medicinal agents as the alkaloids and glucosides are extracted. These are represented by morphine, cocaine, strychnine, atropine, quinine, digitalin, strophanthin aloin, etc., which are extracted from crude drugs imported into this country from overseas.

FIG. 1.

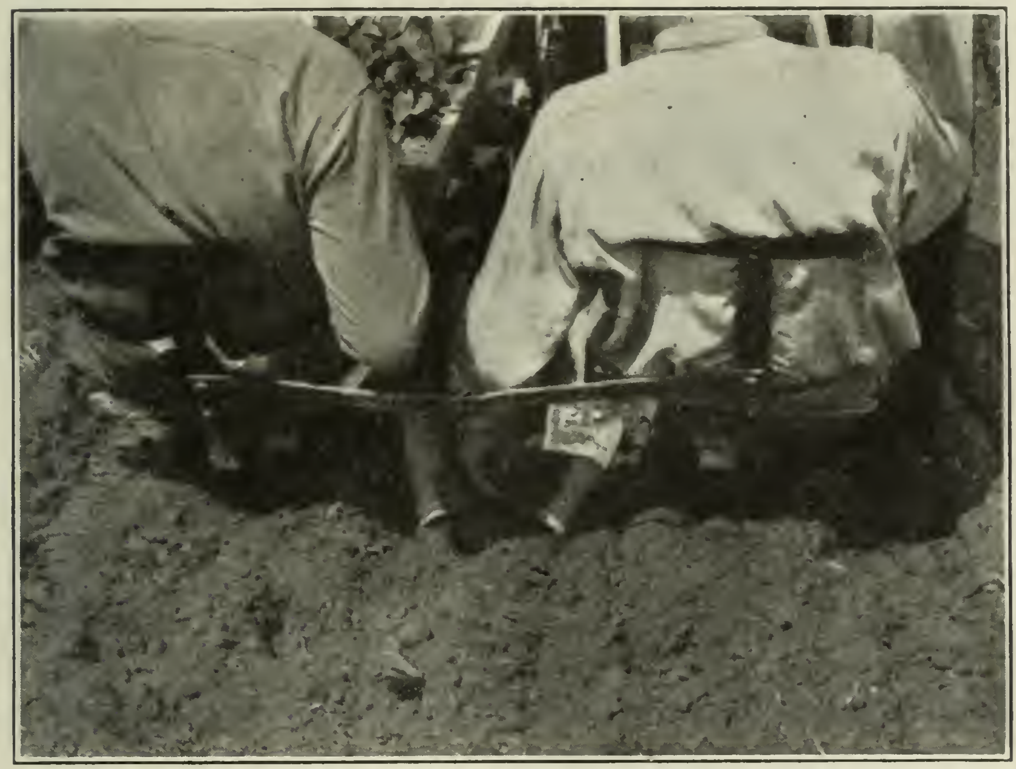


Planting belladonna seedlings at the rate of sixty to the minute.

It is, however, more particularly the botanical drugs which can be grown under proper scientific control in the United States which we shall consider. Among these we find the following important medicinal plants: Aconite, belladonna, and stramonium, the principal source of atropine, digitalis (foxglove), cannabis indica or Indian hemp, the active principal of which is known in India as hashish, the properties of which the elder Dumas so beautifully misdescribes in " The Count of Monte Cristo."

Among our native medicinal plants we also use in fairly large quantity henbane, rhubarb, senna, gentian, golden seal (hydrastis), senega, mandrake, bloodroot, arnica; ajowan seeds, and monada punctata, used in the manufacture of thymol, a specific in the treatment of the hookworm disease, and many others too numerous to mention. If a layman, unaccustomed to the study of such subjects, were to pick up one of the great New York commercial daily newspapers which quote prices in the drug markets and were to glance over the items quoted he would probably be very much astonished at the familiar herbs, roots, and flowers which are made a matter of almost daily barter and sale, the manifold uses of which constitute some of the mysteries of our enormous patent medicine industry. There are warehouses in the heart of New York City filled with great bales of things familiar to our childhood days: cornsilk, daisy tops, red clover tops, laurel leaves, skunk cabbage, flagroot, burdock, dandelion, gentian, lily-of-the-valley, wintergreen, and many another of our old friends of the fields and woods. The inquirer might also be surprised to

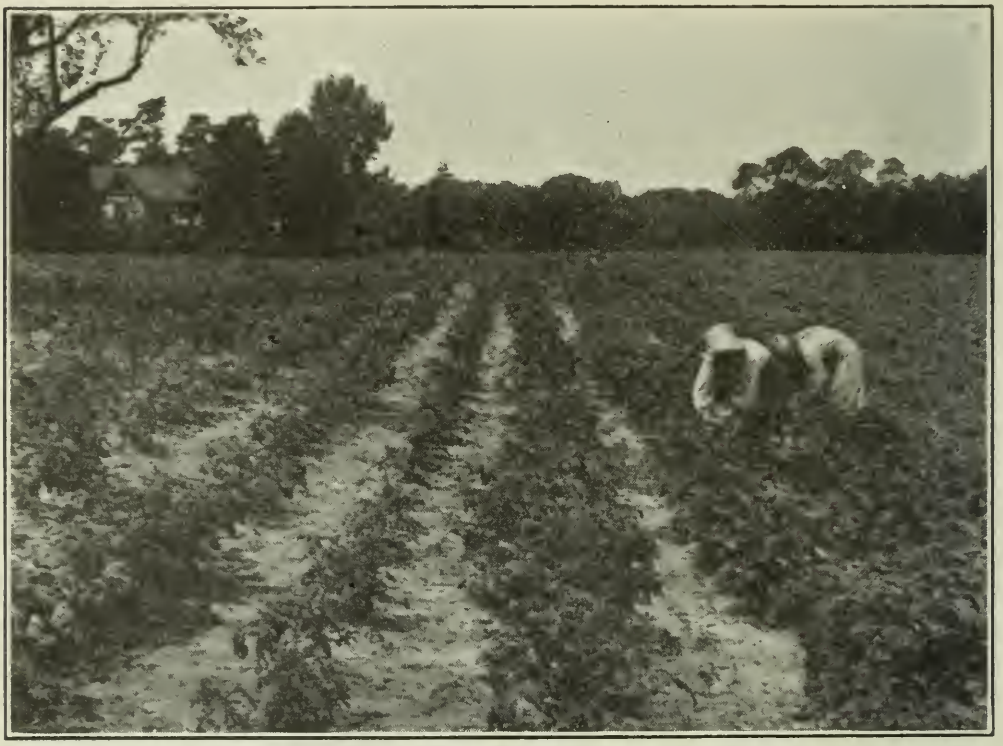
Fig. 2.



A close up view of the two-man planter by means of which belladonna seedlings are set out.

learn that these familiar things command a price varying from cents to dollars per pound and he might even solemnly determine to turn his newly acquired knowledge to profitable purposes and forthwith embark in the combination of business and pleasure of producing and purveying herbs and simples. Unfortunately, however, for this laudable ambition, it would soon become apparent that the labor involved, for instance, in gathering two bales of green corn silk or something else which shrinks to one bale on drying is quite inadequately paid for by the prices offered by the stony-hearted buyers in the New York market. In fact, it would probably be learned that, although America produces more corn silk or something else than all of the rest of the world together, from time out of mind the baled corn silk or something else has been imported from overseas where child-labor laws are unknown and where people's wives, mothers, and grandmothers are more interested in acquiring a few extra pennies a day by working in the fields than they are in acquiring a vote.

FIG. 3.



A seven acre field of belladonna ready for the first harvest.

Seriously speaking, the production of medicinal herbs in America depends very largely on the labor cost, and can be made a profitable enterprise only when it is conducted on a scientific basis and on a sufficiently large scale to absorb the high cost of the labor involved in the tilling, planting, cultivating, harvesting, curing, and packing operations. At the same time, the drug grower faces a most uncertain and precarious market for his wares, for, although his drug plants are needed, the need is strictly limited, and the slightest overproduction is either entirely unsalable or salable at a price less than the cost of production.

A well-known authority on drug growing, Mr. H. C. Fuller, has recently said in effect: "The cultivation and marketing of drugs must be done under an entirely different set of conditions than those obtaining in the growing and selling of vegetables. Much that has been published on the subject is misleading, and the idea that the ordinary farmer can successfully grow drug plants and produce a marketable article is ridiculous. It can be confidently asserted that if the ordinary farmer should undertake the growing of drug plants it would result in failure to him as well as discredit to the efforts of those who are specializing in the subject."

Dr. W. W. Stockberger, the Expert of the United States Department of Agriculture, in charge of drug and poisonous plant investigations, expresses the same fact in the following words:[1]

"If medicinal plant cultivation is to succeed in this country it must be placed on a sound commercial basis, and there are good reasons for believing that this end will not be attained by encouraging a large number of persons to engage in drug growing on a small scale." . . . "If the drug manufacturer is to become permanently interested in medicinal plants produced in this country he must be assured of a fairly large and dependable source of supply. For this reliance must be placed upon well-equipped growers who have sufficient capital to carry on the enterprise effectively."

Still another writer on this subject has recently published the following comments:[2] "In the strictly pharmaceutical field the shortage of crude drugs has been felt more or less keenly since

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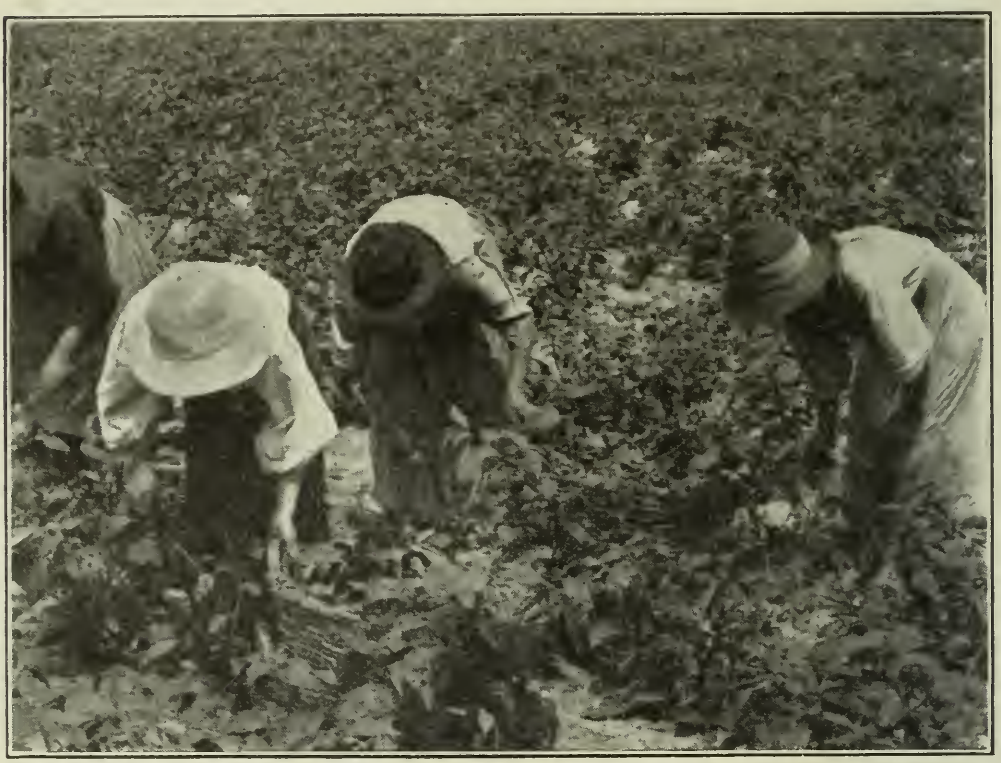
[1] *The Druggists' Circular,* January 18, p. 5; *ibid.,* March 18, p. 106.

[2] Journal Franklin Institute, vol. 185, No. 3, p. 435.

1914, and much misinformation and little information of value have been circulated on the subject. Stocks of many crude drugs have been exhausted, and the cultivation of medicinal plants has not as yet assumed any great proportions in the United States. Those drugs which were obtained from Europe were not cultivated, but grew wild there. It was therefore a simple matter to have them gathered and prepared for market at comparatively small cost. The cultivation of medicinal plants in the United States requires expert labor, the production of artificial conditions of soil and moisture in order to provide as nearly as possible the conditions under which the plants grow in their native habitat, and considerable investment of money. Drug plants have been raised on an experimental scale by the Government and in the drug gardens of various colleges, but it is a very different undertaking to raise them on a commercial scale. American growers of crude drugs were confronted with the necessity of increasing the value of the plants in order to overcome the high cost of cultiva-

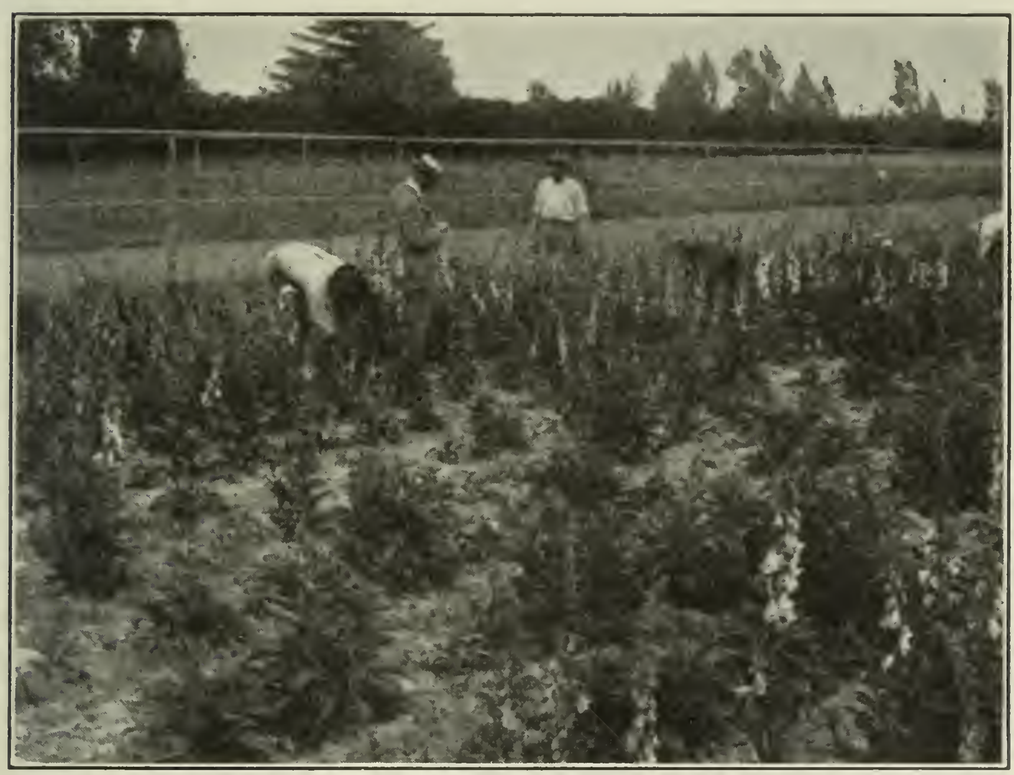
FIG. 4.



Women harvesting belladonna leaves.

tion. It was soon found that cross-pollination would not produce plants containing more active constituents than they do normally, but by careful selection of seed it has been possible to increase the amount of active constituents in such plants as belladonna, digitalis, etc., to three or four times what the Pharmacopœia requires. Furthermore, advanced methods of harvesting these plants have made it possible to secure three or four harvestings in one season, whereas in former years one or two was the limit."

Fig. 5.

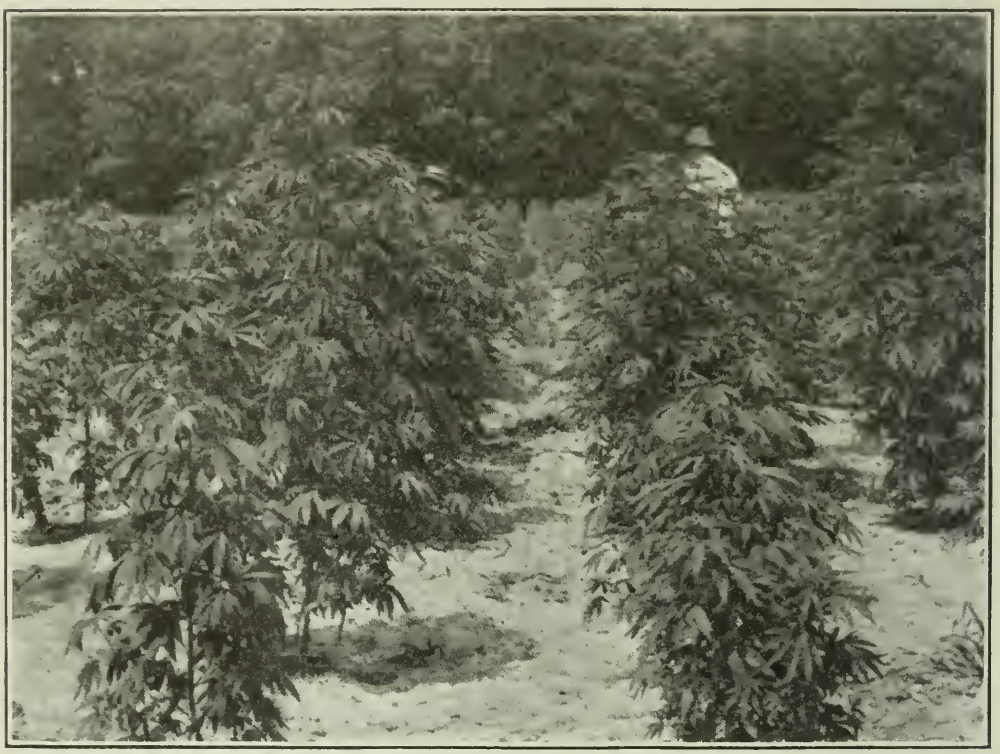


Harvesting digitalis leaves.

The experience gained by the author in the production of certain drug plants extending over the past three years confirms the statements of the experts quoted above. The fact is very clearly brought out that the so-called "backyard" movement, however much it may stimulate vegetable gardening and poultry raising, is not applicable to the growing of medicinal plants. The U. S. P. requirement for dry belladonna herb or leaf calls for an assay showing a content of not less than 0.3 per cent. atropine alkaloid.

Any substantial quantity of active constituent in excess of this prescribed minimum should, if the producer is aware of it, be credited in the price paid by the consumer. The small producer can have no knowledge of the assay value of his product unless he employs the services of a chemical laboratory. Such chemical assays require special highly paid experts in order to obtain accurate results, and the cost of such service is naturally high. In the opinion of the writer, unless a producer is able to hold his belladonna to an assay value at least twice as strong as the U. S. P. requirement it would not be worth producing at all under American conditions. Such high-potency crude drugs can be obtained only by the application to the problem of trained scientific knowledge. Plant breeding through seed selection and a knowledge of just the day to harvest when the alkaloidal content is at the maximum, together with proper control of the drying operations, constitute a large part of the secret of success. All this necessarily hangs upon the results of laboratory investigation, which

FIG. 6.



A field of cannabis.

must go on hand in hand with the agricultural operations. The author and his associates have produced belladonna in bulk running almost one per cent. alkaloid-atropin.

Other important medicinal crops, such as digitalis and cannabis, present a special problem, inasmuch as the active constituents are not determinable by chemical assay, but depend upon certain specific physiological tests which require the services of another group of trained specialists.

Fig. 7.

The Institute of Industrial Research, Washington, D.C., where the drug plants are analyzed and tested.

In marketing crude drugs the pharmacopœial requirements must be met, no matter how irrational these may be. The requirement on cannabis calls for the dried flowering tops of unfertilized pistillate or female plants only. This specification requires that before the male plants pollinate experts must go over the entire crop, plant by plant, and distinguish and destroy every male individual. Immediately the visible crop shrinks approximately fifty per cent., and also adds to its cost of production the cost of this wholesale weeding operation. This requirement also necessitates the seed gardens being remote enough from the main crop to prevent wind-blown pollen from reaching the female survivors. In order to test the necessity for this requirement, the author, in coöperation with Mr. H. C. Fuller, gathered from the seed gardens flowering male tops, which were dried, powdered, and bottled. This sample, together with a pharmacopœial sample bearing distinguishing numbers but no other information, was sent to the physiological laboratory of the Harvard Medical School.

FIG. 8.

Preparing to fill the dryer where the herbs and roots are cured.

The report showed the male sample was the more physiologically active of the two. Although the pharmacopœial requirement is probably a survival of some superstition originating in India, the drug-plant grower is held rigidly to it, and it is extremely unlikely that any buyer would purchase the crude drug in the powdered form, as the dried flowers must be present so that inspection will detect the presence of male plants. If such specifications are annoying to the commercial drug grower, they would be found intolerable by an ordinary farmer who might otherwise feel inclined to undertake the production of this special crop.

All medicinal plants are intensely poisonous to animals, but, curiously enough, most of them are very attractive to predatory insects. Possibly insects share with man a weakness for certain things that would better be let alone. However this may be, the author has determined by actual experiment that the flea beetle consumes about five per cent. of every crop of belladonna grown, in spite of the most liberal use of insecticides and agricultural spraying machinery.

Henbane, the crude drug from which hyoscyamine is made, sells at about four dollars a pound on the dry basis, and is worth it, owing to the eagerness with which insects appear to lie in wait for every green shoot as it appears. In the course of the author's experience potatoes were grown in the neighborhood of henbane, in the hope that it would act the part of a decoy crop. Unfortunately, however, the potato beetles preferred the henbane, and—if we may be permitted to drop into the vernacular—returned to their own homes only after all the other places were shut up.

Among the medicinal plants which the author and his associates have attempted to grow commercially in Virginia and Maryland, many of them successfully, are belladonna, digitalis, cannabis, sage, hydrastis, ginseng, stramonium, monada punctata, pinkroot, valerian, senega, colchicum, etc. Of these, the first two have to be propagated in a greenhouse during the winter in order that the plants, when set out in the field, will be large and vigorous enough to cope with the ravages of insects and crowding out by weeds. The greenhouse soil has to be especially sterilized to prevent the spread of a special fungoid root-rot disease to which belladonna is especially susceptible and which follows the seedlings from the greenhouse to the open fields. During one season the writer lost over fifty per cent. of his belladonna crop, due to root-rot. So suddenly did the disease show itself that on one day the bushy plants, about two feet high, were flourishing in the field and the next day were found wilted down and dying. The roots of belladonna are rich in atropine and are usually dug up and sold after a succession of leaf crops have been gathered, so that the loss from root-rot is most discouraging and baffling.

Ginseng and hydrastis (golden seal) grow in leafy, shady woods and are much appreciated by field mice, which seem to feel that the crops are being grown for their exclusive benefit. Moles, although they do not appear to eat the roots, are most destructive and prefer to burrow along a line of valuable plants rather than go anywhere else. Ginseng is not used as a drug in any country except China, so, if grown, it is only for export. It is doubtful if, under present conditions, its cultivation can be carried on profitably in this country except by specialists in this crop.

This paper has not attempted to discuss drugs or drug growing in their technical aspects, but merely describes a few of the conditions and difficulties encountered by a group of associates who entered the field with no expectation of making large profits, but with the patriotic purpose of demonstrating, if possible, that American methods were capable of making us independent of central Europe with respect to some very necessary medicinals.

Determining the Freshness of Eggs by Photography. G. A. LeRoy. (*Comptes Rendus des Seances de l'Academie des Sciences,* vol. 165, No. 25, p. 1026, December 17, 1917.)—Palming off as fresh, eggs that are several weeks or even months old is quite a common fraud, especially at present, when war-time conditions have caused a scarcity of the product and increased the cost. In the trade, eggs are classified according to freshness by the process known as *candling,* consisting in observing their transparence, which depends mainly upon the dimensions of the air-spaces. With a view to its value in legal expert testimony, the author has developed a more precise method of visualizing the contour of this air-space in such a manner that it constitutes a permanent and comparable legal exhibit. This result has been secured by photographing the eggs by transmitted light upon extremely rapid plates. In this way the contour of the air-space, recorded in true dimension, can be accurately measured. In the course of experiments it was found that radiography yielded distorted images quite inferior to those obtained by visible light.

A large amount of practical information on candling and other features relating to the egg industry will be found in the following publications of the U. S. Department of Agriculture: Professional Paper No. 51, July 20, 1914; No. 224, April 28, 1916. Yearbook Separate 552, 1910; 596, 1912; 647, 1914. Bureau of Chemistry, Circular No. 98, July 31, 1912.

SOME POINTS REGARDING CALORIMETER EFFICIENCY.*

BY

WALTER P. WHITE.

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THE use of the calorimeter is to-day extending rapidly, especially for fuel testing. At the same time, some new types of calorimeter are being introduced whose value varies greatly according to the work to which they are put. There is thus a double reason for considering the sources of calorimetric error and the advantages of different types of instrument. The present paper attempts this task, and does so with reference rather to the moderately high precision desirable in commercial work than to the higher precision attained in special researches.

Calorimetric experiments are practically always done by passing the heat to be measured into a known mass of water and observing the resulting temperature rise. The heat, ΔQ, is then determined in accordance with the well-known equation: $\Delta Q = C \Delta \theta$, where $\Delta \theta$ is the temperature change and C the capacity for heat of the calorimetric body; that is, of the water together with the containing vessel. This determination would involve nothing but a couple of temperature measurements were it not for the fact that there is no insulator for heat, and that therefore there is practically always some heat flowing to or from the calorimeter. This *thermal leakage* must be determined, usually by a combination of observations and calculations. It causes less actual error than is often supposed, but it dominates the whole subject of calorimetry, and is responsible for nearly all the characteristic features of calorimetric practice. Thus, in order to treat the leakage in a definite way the surrounding temperature must be controlled more or less; then, in order to prevent the leakage from making the calorimeter temperature non-uniform and therefore uncertain, there must be stirring, which is the reason for using a liquid. This, in turn, may bring difficulty from evaporation and irregular stirring, and, finally, some temperature differences remain uncorrected (especially in the solid parts), constituting "lags," which are, mathematically, the most complicated part of the whole subject, though they can, fortunately, be handled very simply in work of moderate precision.

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* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, November 15, 1917.

Aside from blunders and exceptional occurrences, the sources of error in ordinary calorimetry seem completely covered by the following list:

A. The main temperature measurements.
B. The value taken for the heat capacity of the calorimetric body.
C. The associated determination.
D. The thermal leakage or its consequences, including:
  a. Control of the external temperature.
  b. Control of the calorimetric temperature (*i.e.*, efficiency of stirring).
  c. The heat produced by stirring (which may be irregular, owing to irregular speed of stirring).
  d. Evaporation.
  e. Lags, if neglected or varying.

A. The temperature measurement seems to call for little comment, save perhaps to say that from two to four individual observations are needed, so that the final error *may* be two or four times that of a single reading, though the *average* final error will not be so large as that. Thus, a mercury thermometer, if accurate to 0.001°, will, in itself, give a precision of 1 per mille or a little better with a temperature rise of 4°; this is, however, rather high precision for a mercury thermometer. The electric (resistance) thermometer will do better—about ten times as well with the best instruments in competent hands. It, of course, requires a more elaborate installation. Many observers, however, consider the precautions and corrections needed with it less objectionable than those involved with the mercury thermometer, and the extra precision of the electric thermometer is a desirable thing, even in cases where the other may seem good enough. A precision which is just enough and no more for the purpose in hand looks very shrewd and economical, on paper, and may prove not unsatisfactory so long as everything goes well; but if unexpected errors need investigation or checks upon the accuracy are desired, as is pretty certain to happen sooner or later, it is exceedingly comfortable to have even a four- or five-fold excess of precision, and in as many departments of the work as possible. The *thermo-electric* thermometer is not only capable of higher ultimate precision than the resistance thermometer in measuring small temperature differences, but is, to judge from my own experience, more reliable, and less troublesome in its need for precautions, though in some other evident ways it is less convenient. The methods necessary with it, however, are not so generally understood, and it is not regularly manufactured at present.

B. For determining the heat capacity of the calorimetric body the practice of calibrating by means of a known quantity of heat, obtained either electrically or by means of a standard substance, has so many advantages, and has already become so widely used, that no other seems to deserve consideration. With this method, if uniform conditions are preserved, the error of the calibration becomes little more than the average error of a number of determinations, which can be made as numerous as is desired.

C. The associated determination must be considered for a fairly evident reason. There is no such thing as bottling up a quantity of heat for subsequent measurement; heat cannot even be passed, unchanged, directly from one calorimeter to another. The heat must be produced as measured, and the only way to give the measurement significance is to express it as a ratio between the quantity of heat and the quantity of the thing (reacting chemical, electric energy, etc.) yielding the heat. An error in one of the terms of this ratio has the same final effect as a corresponding error in the other. This is merely a formulation of what is pretty generally understood in individual cases. In commercial coal testing, for instance, it is generally recognized that the sampling of the coal is often the greatest source of uncertainty, and it is futile to strive for a calorimetric precision very far ahead of the uniformity which it seems worth while to seek in the sampling.

D. The *thermal leakage* and its calculation are responsible, as has been said, for most of the problems and complications in calorimetry. In calculating, the leakage is taken as the product of the *leakage modulus*, or rate of leakage per degree of *thermal head* (thermal head: difference of temperature between calorimeter and environment), multiplied by the integrated value of the thermal head for the experimental period. The standard method is to determine the leakage modulus by *rating period* observations on the rate of cooling of the undisturbed calorimeter; if two such rating periods are used it is possible to determine the thermal head without measuring the environing temperature, provided this temperature does not change appreciably during the experiment. This procedure also eliminates the effect of the heat produced by the stirring, which would otherwise need especial attention. The method is familiar, and does not need detailed consideration here. This method is almost necessary if the environment consists of several indefinite bodies at different temperatures, but it involves having three observation periods. If, however, the leakage modulus is the same from day to day, and if the environing temperature is measured, or is kept at a known value by a thermostat, the leakage can, after suitable preliminary work, be determined merely from observations on the calorimetric temperature during the experimental period, and no other period is needed, unless occasionally as a check. Of course, this demands (1) that the environment be all at a single definite temperature—that is, practically, that it be a stirred body of water more or less completely enclosing the calorimeter (though with an air space between, of course), and (2) that the calorimeter always contain the same amount of water and be located, to a fraction of a millimetre, perhaps, always in the same position within the jacket.

To determine the leakage in this way not only saves time and labor, but even promotes accuracy by eliminating the errors of the temperature measurements needed in observing the leakage rates. That is to say, instead of a rate determined separately, with some error, for each experiment, the observer uses a rate determined once for all with more accuracy by numerous experiments. Using this method, the Bureau of Mines observers have, as they state, usually attained in their regular routine procedure, an agreement of 1/7000, which closely approaches the best yet reported for the most elaborate special researches. Of course, this precision was realized only where the sampling error was eliminated, and it is more than is needed in regular work, even for the Bureau of Mines. This method, it may be added, should not be relied upon in any particular installation until it has been shown that the leakage modulus is in fact as constant as it needs to be. Other things than the position of the calorimeter may be of importance here. For instance, if metallic parts of any kind run from the calorimeter through the jacket to the air of the room outside it, a change in room temperature is very apt to alter the leakage rate unless proper precautions are taken. Evaporation is prevented in the Bureau of Mines calorimeters.

If the determinations made are nearly the same day after day, the temperature during the experimental period will always rise along almost the same curve, and its integrated value may without error be taken as the same for any given total temperature rise. If, in addition, the jacket temperature and the initial calorimeter temperature are always the same, the integrated thermal head will always bear the same relation to the total temperature, and the amount of thermal leakage will be simply a certain constant (and small) percentage of the total temperature rise. No attention, therefore, need be paid to the thermal leakage in working up the results. This is essentially the Bureau of Mines procedure. This treatment of the thermal head saves only a little labor, not time or error, and hence is much less important than making the jacket a thermostat. It is, however, a fact of some importance that where the determinations made are sufficiently alike a faulty treatment, or even a total neglect, of the thermal leakage will usually produce no great error in a calorimeter *calibrated by the user,* if the jacket is complete and is maintained constant.

D, a. The temperature change from leakage of a well-designed calorimeter of ordinary size will be less than 0.015 of the thermal head in five minutes; hence for five-minute experimental periods the uncertainty of the jacket temperature may be at least thirty times that in the principal readings. Evidently any difficulty there may be as to this temperature will be a matter of control or uniformity, and not of measurement.

D, b and *c.* The matter of stirring seems fairly well covered by the recommendation of the joint committee on coal analysis of the American Society for Testing Materials and of the American Chemical Society,[1] that the stirring be vigorous enough to heat the calorimeter nearly 0.001° per minute, and regular enough so that the variation in heat is negligible. This is certainly sufficient with a reasonably well-designed calorimeter. The heat varies as the cube of the speed of stirring, so that a variation of

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[1] *Jour. Ind. and Tech. Chem.*, 9, 106 (1917).

1 per cent. in speed produces a variation of 3 per cent. in heat production.

D, d. No data exist as to the relative probable error from evaporation, but this does not seem likely to be serious in commercial work so long as evaporated water does not condense on the cover and drop back into the calorimeter. The prevention of evaporation is very desirable in work of high precision and is easy enough to be reasonable in nearly all cases, since it can be effected, without the introduction of any other error, by covering the calorimeter with an exceedingly thin metal cover. This cover need not bend down to touch the water, though it may well do so. If it does not, the water should be, to a millimetre, always at the same distance below it—say a centimetre. Covers of wood, rubber, or other poorly conducting material have no other recommendation than possible cheapness. (A proof of this statement will be published later.) It does not necessarily follow that it is desirable to scrap such covers now in use, however.

Further Practical Conclusions.—(1) From the preceding discussion it appears that uniformity of conditions is, in the uniform determinations of commercial work, almost sufficient in itself to secure precision, so far as thermal leakage is concerned, since effects which would otherwise be errors tend to cancel. The joint committee report cited above says that the calorimeter jacket "should" contain water, which is stirred. There are two different reasons for this. The uniform temperature of a stirred jacket is, of course, desirable, but it might not seem necessary, since an unstirred jacket always started at the same temperature relative to room and calorimeter would be likely to give *uniform* results. But to have a jacket full of water which is stirred is the easiest way to provide for getting it at the same relative temperature each time; moreover, the provision of this particular feature is seldom likely to prove expensive.

(2) To convert the stirred jacket into a thermostat is more expensive, since it requires a regulator and also demands if it is to be of real value that the jacket be brought *above* the calorimeter so as to surround it with practical completeness. But the gain in time and labor, as well as in accuracy, from using such an installation is very considerable.

(3) The joint committee report advises having the initial calorimeter temperature so far below that of the jacket that the

final temperature is less than a degree above it, and the total resultant thermal leak is near zero. Two advantages are attributed to this procedure: one, that evaporation is diminished; the other, that the total leak is small. The diminution of evaporation is as likely to increase the error as to decrease it,[2] and the smallness of the total leak is practically of no advantage in the case treated, where two rating periods are supposed to be run, since in that case the total magnitude of the leakage has no effect on the error. (This appears to be a fact not generally known. Proof of it will probably be published later elsewhere.) Little is *lost* by thus reducing the total amount of leakage, but it would be misleading, in considering the adoption of this method rather than some other, such as the Bureau of Mines method, to suppose that it had any real advantage in this particular direction.

(4) A calorimeter has been advertised as "adiabatic" which is characterized mainly by the use of a vacuum jacketed glass vessel instead of the usual metal cup. To call such an arrangement adiabatic is pure humbug; it has a thermal leakage, which may be one-third or may be one-fourth as great as that of an ordinary calorimeter. To claim *some* advantage from the smaller leakage is legitimate; for it may enable an equal degree of precision to be reached with less care as to conditions.

(5) Attempts are making to utilize in commercial work calorimeters which are really adiabatic; that is, in which the jacket temperature can be rapidly changed and controlled so that it can be kept the same as that of the calorimeter during an experiment. Some of the proposed apparatus is admirable in its ingenuity and effectiveness, but there is still reason to doubt if it is worth while. The adiabatic method in calorimetry, like most methods in every subject, differs greatly in value according to the conditions of its use. In aneroid (fluidless) calorimetry and in long-timed determinations it is often absolutely indispensable, but in short experiments its value is much less. If we refer to the sources of error listed in this paper, *A, B,* and *C* are scarcely affected one way or the other by the adoption of the adiabatic method; nor are the temperature distribution effects *D, b, D, c,* and *D, e.* Evaporation (*D, d*) is greatly diminished, but easier

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[2] Owing to the fact that the leakage rate differs some 30 per cent., according as evaporation is or is not occurring; that is, suddenly becomes 30 per cent. greater when the calorimeter temperature passes above the jacket temperature.

ways have already been given of securing this result, which is not of first importance, anyway, in commercial work. The control of jacket temperature (*D, a*) will evidently be more perfect where this temperature is not greatly changed, so that here the adiabatic method is actually worse, though the inferiority is probably not serious. One real advantage of the adiabatic method is in ease, not precision, and consists in the avoidance of the labor of calculating the thermal leakage. But in commercial work this advantage is still more easily obtained through a thermostat, as at the Bureau of Mines. Of course, this method calls for a constant leakage modulus, which the adiabatic does not. But the results show that the chances of error from inconstancy of this modulus are very small. The most serious danger of variation in the modulus, that coming from the influence of room temperature changes, is quite as great with the adiabatic method. In *uniform short-timed* determinations, then, the adiabatic procedure, in return for the expense and manipulation it demands, appears to offer no advantage that cannot be more easily secured in other ways.[3]

(6) If a massive block of metal is used as the calorimetric body, equalization of temperature is less perfect than with a stirred liquid, but the difficulties and annoyances of stirring and evaporation are completely banished. The relatively imperfect equalization is evidently less serious in the uniform determinations of commercial work, so that for such work this kind of calorimeter might prove very desirable. Féry has proposed such an instrument, using the steel bomb alone as the calorimetric body, and measuring temperature thermo-electrically. In striving for simplicity, he has, as it seems to me, attained an altogether unnecessary crudeness in several respects. Apparently, a much more

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[3] In some recent work of high precision (*J. Am. Chem. Soc.*, 39, 2110, 1917) the adiabatic method was adopted mainly because a stationary final calorimeter temperature was thought necessary for satisfactory reading of the resistance thermometer. It is safe to say that the necessity, in so far as it existed, may fairly be attributed to some deficiency or peculiarity of the electric installation used, and is not an inevitable disadvantage of that type of thermometer, although the usual installation is not the most convenient that could be used for reading changing temperatures. So far as the precision of commercial work is concerned, there appears to have been no general difficulty in reading changing temperatures, as is indeed shown by the disregard of the possibility of making their reading more convenient.

accurate instrument could be realized which would not be harder to manipulate. The final success of such an instrument—that is, its net superiority to existing calorimeters—cannot be guaranteed in advance of actual experience, but the idea seems promising.

In conclusion it may be said that a calorimetric installation with a stirred, thermostated jacket and an electric thermometer appears thus far to have given the best combination of precision and ease of operation, and that in the main the electric thermometer is responsible for the precision, the thermostat for the ease of operation.

High-strength Steel from Nickel-copper Iron Ore. Anon. (*Engineering News-Record,* vol. 80, No. 17, p. 812, April 25, 1918.) —Large-scale experiments to produce a high-strength steel from Sudbury ores, in which both copper and nickel are combined with the iron, show that a metal giving test results quite equal to those of nickel-steel as used for bridges and for forgings can be produced at low cost. The new product has been named " Nicu " steel and is made by the Nicu Steel Corporation, East Montreal, Canada. Material with an ultimate strength of 70,000 to more than 100,000 pounds per square inch, a yield-point of 50,000 to 80,000 pounds per square inch, and of satisfactory ductility for bridge or ordnance purposes is produced at costs which may be brought down as low as $30 to $35 per ton.

Figures of tests on the material produced in the experimental smelting are given by Lieut.-Col. R. W. Leonard in a paper read before the Canadian Society of Civil Engineers, March 28, 1918. In ten heats run at East Montreal, steel was produced having carbon content from 0.17 to 0.73 per cent., silicon from 0.012 to 0.032 per cent., sulphur always below 0.048 per cent., and phosphorus generally below 0.01 per cent. The sum of nickel and copper ranged from 1¼ to 2½ per cent., copper usually being about one-fifth of the total. A typical strength test, one made by Dr. Alfred Stansfield, of Magill University, Montreal, resulted in a tensile strength of 96,500 pounds per square inch, a yield-point of 52,800, an elongation (in two inches) of 24.3 per cent., a reduction in area of 50.8 per cent., and a 180-degree bend test flat without cracking. This was a specimen of " Nicu " steel in which the combined nickel and copper was 2.26 per cent. For comparison it may be noted that 3¼ per cent. nickel-steel is commonly specified to have an elastic limit not below 50,000 pounds per square inch and ultimate strength of 85,000 to 100,000 pounds per square inch, with an elongation of 16 to 17 per cent. in 8 inches, and a reduction in area greater than 30 per cent. " Nicu " steel, it is stated, has not as yet been manufactured on a commercial scale.

Direct smelting of nickel-bearing iron ores to nickel-iron pig has been done in the past. With the same purpose of producing a copper-free nickel alloy, much study has been given the Lake Superior nickel-copper-iron ores to produce nickel pig and nickel steel with minimum admixture of copper. On the other hand, nickel-copper steel has been made in the United States in several instances by adding monel metal to steel.

Concrete Metal Planing Machines. E. VIALL. (*American Machinist*, vol. 48, No. 15, p. 603, April 11, 1918.)—The urgent demand for speed of construction incident to war-time activity is giving rise to some radical departures from established practice in engineering construction. A notable example is found in the recent rapid development of the relatively old idea of building vessels of reinforced concrete. Ships of several thousand tons built of this material are now under construction. Another remarkable innovation is found in the method of lathe construction employed by Lucien Q. Yeomans, in which the ways are made of cold-rolled shafting held in place in the unfinished bed-casting by the use of Babbitt metal. The latest remarkable departure by the same builder is in the application of reinforced concrete to replace cast-iron in the structure of large metal-planing machines.

These machines were built by the Amalgamated Machinery Corporation, Chicago, Ills. They comprise a battery of four machines, each with a bed 184 feet long, 17 feet across at its widest place, and 18 feet in height, measured from the bottom of the bed to the top of the housing. Approximately 212,000 pounds of iron and steel castings were used in each machine, and about 13,500 cubic feet of concrete reinforced, with 34,000 pounds of steel bars. The bed consists of a concrete girder with a high percentage of steel reinforcement surmounted by relatively shallow cast-iron ways. The depth of the girder over the ways is 8 feet 6 inches. The ways are made in sections 12 feet long, 4 feet 10 inches wide, and 13 inches through at the deepest point, and have one flat and one V-guide 10 inches wide. The table is also made in sections about 12 feet in length. After the sections have been fastened together concrete is poured into box-like sections, making one long, solid monolith of concrete and iron.

No automatic means of feeding is supplied; each cutter head is controlled independently by hand from a platform at the top of the housings. The power required is furnished by two 40-horsepower, three-phase, sixty-cycle motors, making 1800 revolutions per minute. The machines were built primarily for the purpose of planing the beds of large gun-boring machines for the government. While built alike for a special purpose, they may be made in various sizes if necessary, and the short time needed to complete them should make the system of construction employed a valuable innovation where the greatest economy of time is imperative.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

1. *In Soils from Widely Different Sections.*—The soils examined were from various parts of the United States; soils from twenty states make up the list. They vary from very unproductive to extremely fertile soils. Aldehydes were found in soils from nine states as widely separated as New York and Mississippi or Oklahoma. Its presence is therefore not confined to any locality.

2. *In Soils of Different Texture.*—The soils in which aldehyde occurred are not soils of any specific type or texture. The above list of soils containing aldehyde comprises clays, clay loams, silt loams, silty clay loams, loams, stony loams, fine sandy loams, and very fine sandy loams. There is therefore no apparent relation with soil type or texture.

3. *In Unproductive Soils.*—The unproductive soils examined can be divided into two classes: (1) Garden soils, comprising soils which have been highly fertilized and manured, heavily cropped and intensively cultivated, and later failed to produce good crops. This class includes several greenhouse soils. (2) Field soils, growing general farm crops with ordinary farm methods of cultivation.

Fourteen poor garden soils were examined, five of which contained aldehydes. All of these soils were very unproductive and failed entirely or grew very poor garden crops. Nine of the thirty unproductive field soils examined contained aldehydes.

4. *In Productive Soils.*—Of the thirty productive soils examined, three contained aldehydes. These were the Aurora silt loam, from Miller County, Missouri; Norfolk very fine sandy loam, from Pender County, North Carolina and Dekalb silt loam, from Preston County, West Virginia.

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* Continued from page 186, vol. 186, August, 1918.

5. *In Acid, Alkaline, and Neutral Soils.*—It is interesting to note that some of the soils which contained aldehydes were acid, some neutral, and others alkaline. Three of the garden soils were acid, one was alkaline, and one was neutral. Of the field soils which contained the aldehyde, ten were acid, one alkaline, and one neutral.

6. *In Soils Growing Different Crops.*—Four of the soils which were found to contain aldehydes were garden soils and had been used for growing garden crops continuously for several years. One was a greenhouse soil and had grown carnations and roses. Twelve of the soils in which aldehyde was found were used for the growth of general field crops. A rotation of several crops was practised on most of these soils. At the time the samples were collected three were in grass, four were growing corn, three were growing cotton, one was in wheat, and one was fallow. These observations, together with the fact that no aldehydes were found on other soils growing the same crop, would seem to indicate that no close relation exists between the crop being grown and the presence of aldehyde.

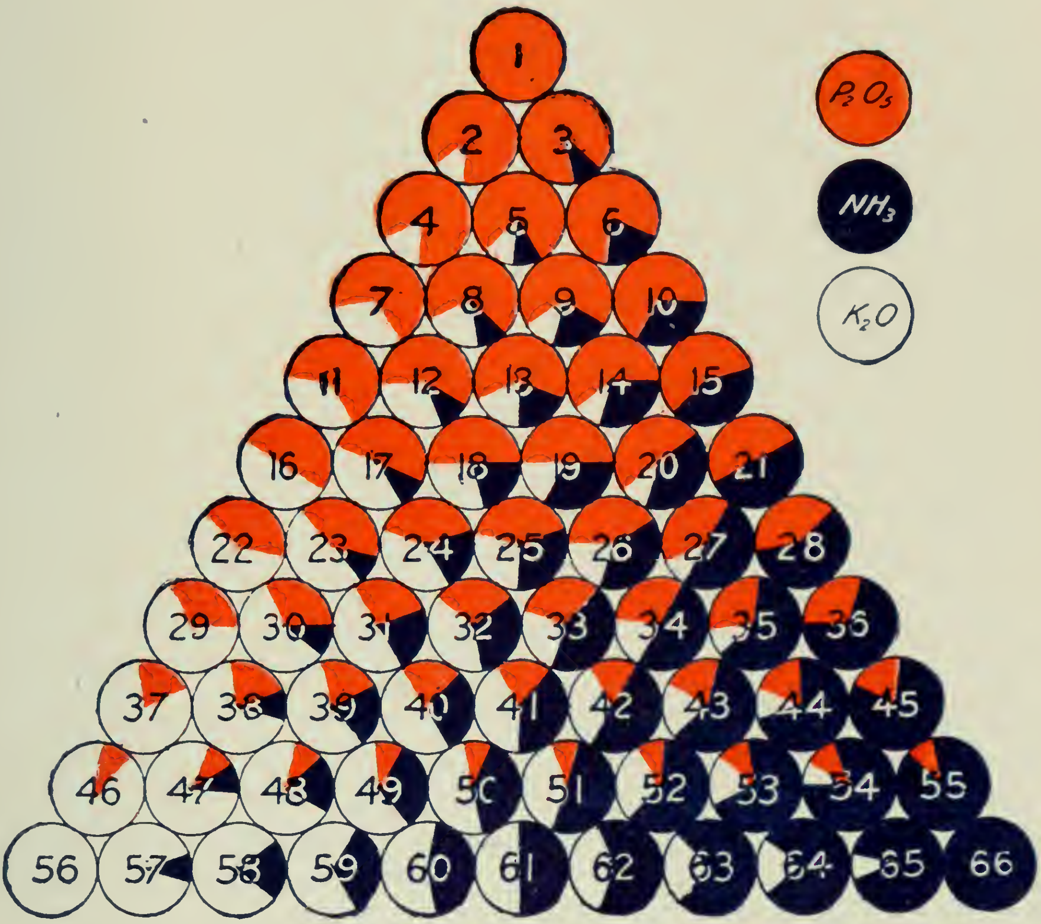
EFFECT OF ALDEHYDES ON PLANTS IN SOLUTION CULTURES.

A thorough study of the action on plants of six aldehydes was made and reported in the following pages. The investigation concerned itself with the action of salicylic aldehyde, vanillin, heliotropine, benzaldehyde, formaldehyde, and paraformaldehyde on plants, first in distilled water and then in nutrient-culture solutions. The two compounds, salicylic aldehyde and vanillin, which have been definitely identified in soils, were further studied in soils in pots and in the field, the results of which are given in a later section. It has not been possible thus far, nor has it seemed wise, to study all of these aldehyde compounds in field experiments. These two were selected for this more extended study which were definitely known to occur in soils. In this section are given the experiments with each compound in water- and nutrient-culture solutions.

CULTURE SOLUTIONS.

In studying the effect of these aldehydes on growth, wheat seedlings were grown in aqueous solutions containing the ordinary fertilizer salts, calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained calcium acid phos-

FIG. V.



Triangular diagram, with the circles representing the 66 culture solutions numbered.

β

phate only, some sodium nitrate only, and some potassium sulphate only. Other solutions were composed of mixtures of two salts—sodium nitrate and calcium acid phosphate, sodium nitrate and potassium sulphate, and calcium acid phosphate and potassium sulphate. Still other solutions had all three constituents in various proportions. The concentration of all the solutions was 80 parts per million of the fertilizer ingredients, P_2O_5, NH_3, and K_2O. In cultures containing only one fertilizer salt—for instance, calcium acid phosphate—the concentration was 80 parts per million of P_2O_5. If two salts were present—for instance, calcium acid phosphate and sodium nitrate—the concentration was 80 parts per million of $P_2O_5 + NH_3$. If all three salts were present, the concentration was 80 parts per million of $P_2O_5 + NH_3 + K_2O$. The ratios of these constituents varied in 10 per cent. stages. In all there were 66 different cultures of nutrient solutions.

The triangular diagram, as suggested by Schreinemachers (40) and later by Bancroft (4), which had been of great service in physical chemistry where consideration of percentage composition of three component parts is concerned, is used as a guide. This system has been extensively used by Schreiner and Skinner (50, 51, 54, 56) in nutrient-solution studies. The diagram is shown in Fig. 5: it is an equilateral triangle in which the extreme circles at the angles represent 100 per cent. respectively of the ingredients, P_2O_5, NH_3, and K_2O, as shown in the diagram. The P_2O_5 is represented in red, the NH_3 in blue and the K_2O in white. Each side of the diagram is divided into 10 equal parts, represented by circles. If we consider the line representing the base of the triangle, it is obvious that the circle which represents 100 per cent. K_2O (56 in the diagram) represents at the same time 0 per cent. NH_3, and the circle 100 per cent. NH_3 (66) likewise represents 0 per cent. K_2O. If we take a point half-way between these two points—for instance, circle 61—we have a mixture of the two salts in equal proportions; *i.e.*, a mixture of the salts represented by that point will be 50 per cent. K_2O and 50 per cent. NH_3. Similarly, circle 16 represents 50 per cent. K_2O and 50 per cent. P_2O_5, and circle 21 represents 50 per cent. NH_3 and 50 per cent. P_2O_5. If we take a circle nearer to either of the corners, we will have a higher percentage of that ingredient and a correspondingly lower percentage of the other. For instance, at circle 59 the composition is 70 per cent. K_2O and 30 per cent. NH_3; at 29 it is likewise 70 per cent. K_2O, but 30 per cent. P_2O_5; at 64 it is 20 per cent. K_2O and 80 per cent. NH_3; at 45 it is likewise 80 per cent. NH_3, but 20 per cent. P_2O_5.

As stated above, circles on the base line 56 to 66 represent mixtures containing no P_2O_5. The next line above this, namely, 46 to 55, represents mixtures containing throughout 10 per cent. P_2O_5, but varying amounts of the other two constituents. Similarly, the line 37 to 45 represents throughout 20 per cent. mixtures of P_2O_5; line 29 to 36, 30 per cent. mixtures of P_2O_5, and so on upward until circle 1, the apex of the triangle, is reached, where the composition is 100 per cent. P_2O_5, as already explained. Similarly, points on the line 1 to 66 represent 0 per cent. K_2O; line 2 to 65 represents 10 per cent. K_2O, but varying amounts of P_2O_5 and NH_3, and so on until at circle 56 the composition is 100 per cent. K_2O. Likewise points on the line 1 to 56 represent 0 per cent. NH_3; line 3 to 57 represents 10 per cent. NH_3, but varying amounts of P_2O_5 and K_2O, and so on until at circle 66 the composition is 100 per cent. NH_3. It is therefore obvious that any circle within the triangle represents a mixture composed of the three constituents, its position in the triangle being determined by the composition; namely, the percentage of the three component parts, P_2O_5, NH_3, and K_2O. For instance, circle 12, being on the 60 per cent. phosphate line, represents this composition of P_2O_5—namely, 60 per cent.—and being at the same time on the 10 per cent. NH_3 line and the 30 per cent. K_2O line it represents 10 and 30 per cent. of these constituents, respectively. The composition of the mixture represented by this circle is therefore P_2O_5 60 per cent., NH_3 10 per cent., K_2O 30 per cent.; *i.e.*, the ratio of these constituents in the fertilizer mixture is 60–10–30, or 6–1–3. Similarly, the point 34 represents a mixture of the composition P_2O_5 30 per cent., NH_3 50 per cent., K_2O 20 per cent., or a fertilizer ratio of 3–5–2.

The triangle therefore represents single fertilizer constituents at the apices or vertices, mixtures of any two constituents along the boundary lines of the triangle, and mixtures of all three constituents within the triangle.

In the following table is given the composition represented by each of the 66 circles in the diagram:

Two sets of cultures were prepared: to one set were added merely the nutrient salts; to a similar set the aldehyde compound to be tested was added to each culture, in addition to the nutrient salts. The culture solutions were contained in wide-mouth bottles, holding 250 c.c. and 10 wheat seedlings were grown in each culture in a manner similar to that described in Bureau of Soils Bulletin No. 70. The culture solutions were changed every three days, four changes being made in the course of the experiment. The solutions were analyzed for nitrates immediately after each change. The phosphate and potassium were determined on a composite solution of the four changes. Observations on the general development of the plants and the effect on root growth and appearance were made during the experiment and photographs were taken. At the termination of the experiment the green weight was taken and recorded.

For the purpose of preparing the 66 culture solutions needed in this investigation, stock solutions of the three salts—calcium acid phosphate, sodium nitrate, and potassium sulphate—were prepared separately. The salts used were chemically pure salts, and were dissolved in each case in physiologically pure water.

TABLE III.

Sixty-six Possible Ratios of the Three Fertilizer Constituents P_2O_5, NH_3, and K_2O in 10 per cent. stages.

Circle No.	Ratio or percentage composition			Circle No.	Ratio or percentage composition			Circle No.	Ratio or percentage composition		
	P_2O_5	NH_3	K_2O		P_2O_5	NH_3	K_2O		P_2O_5	NH_3	K_2O
1	100	0	0	23	40	10	50	45	20	80	0
2	90	0	10	24	40	20	40	46	10	0	90
3	90	10	0	25	40	30	30	47	10	10	80
4	80	0	20	26	40	40	20	48	10	20	70
5	80	10	10	27	40	50	10	49	10	30	60
6	80	20	0	28	40	60	0	50	10	40	50
7	70	0	30	29	30	0	70	51	10	50	40
8	70	10	20	30	30	10	60	52	10	60	30
9	70	20	10	31	30	20	50	53	10	70	20
10	70	30	0	32	30	30	40	54	10	80	10
11	60	0	40	33	30	40	30	55	10	90	0
12	60	10	30	34	30	50	20	56	0	0	100
13	60	20	20	35	30	60	10	57	0	10	90
14	60	30	10	36	30	70	0	58	0	20	80
15	60	40	0	37	20	0	80	59	0	30	70
16	50	0	50	38	20	10	70	60	0	40	60
17	50	10	40	39	20	20	60	61	0	50	50
18	50	20	30	40	20	30	50	62	0	60	40
19	50	30	20	41	20	40	40	63	0	70	30
20	50	40	10	42	20	50	30	64	0	80	20
21	50	50	0	43	20	60	20	65	0	90	10
22	40	0	60	44	20	70	10	66	0	100	0

For the calcium acid phosphate solution 1.776 grammes of $CaH_4(PO_4)_2.H_2O$ per litre was used. This solution has a concentration of 1000 parts per million of P_2O_5. The sodium nitrate solution was prepared by using 5000 grammes of $NaNO_3$ per litre. This solution is equivalent to a concentration of 1000 parts per million of NH_3. The potassium sulphate solution was prepared by dissolving 1.852 grammes of K_2SO_4 per litre. This solution has a concentration of 1000 parts per million of K_2O.

The amount of culture solution used in each culture bottle being 250 c.c., it follows that every 2 c.c. of these 1000 parts per million stock solutions will represent 8 parts per million in the culture solution when this is diluted to the capacity of the bottle; *i.e.,* the successive addition of 2 c.c. of the stock solution gives the 10 per cent. differences desired in putting up the 66 solutions. In putting up the 66 cultures it was found desirable to calibrate each bottle for 250 c.c. capacity and to number them consecutively from 1 to 66. Bottles in which the 250 c.c. mark was either high or low, especially those which would submerge the seeds when filled, were discarded, only those being used which brought the surface of the liquid from one-half to one-fourth of an inch from the top.

These 66 bottles were then arranged in triangular form, as illustrated diagrammatically by Fig. 5.

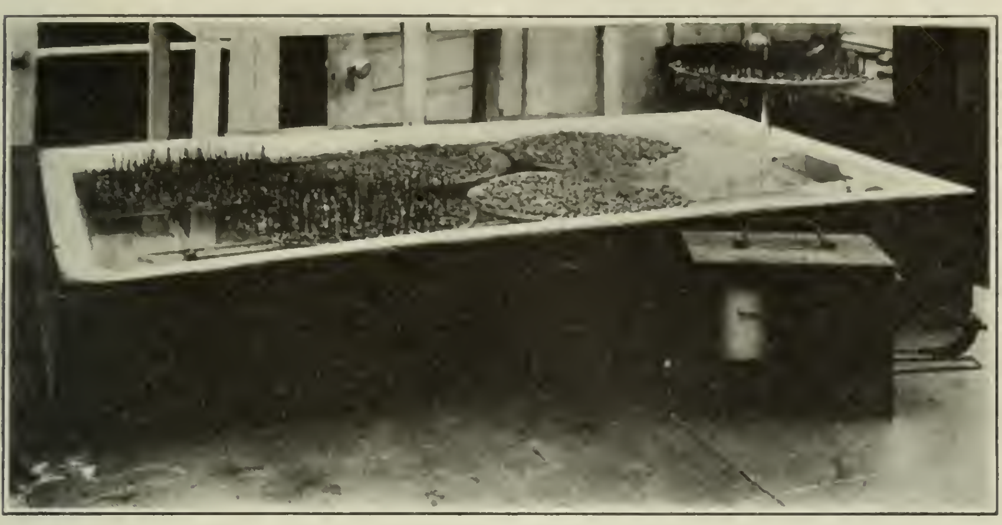
The necessary amount of the 1000 parts per million stock solution above described was measured from a burette. For instance, in adding the requisite amount of nitrate to the set of culture bottles, the line of bottles 1 to 56 received no nitrate solution, the line of bottles 3 to 57 received 2 c.c. each; the line 6 to 58, 4 c.c. each, and so on, increasing 2 c.c. with each successive line, the culture No. 66 finally receiving 20 c.c. of the nitrate solution. Likewise, in adding the requisite amount of potash, the cultures in line 1 to 66 received none, the cultures in line 2 to 65 received 2 c.c. each; in line 4 to 64, 4 c.c. each, and so on up to culture 56, which received 20 c.c. of the potash solution. The phosphate solution is added in the same manner, none to cultures in line 56 to 66, 2 c.c. to cultures in line 46 to 55, and so on up to culture 1, which received 20 c.c.

Each bottle received, therefore, a total of 20 c.c. of one, two, or three of the stock solutions, depending upon whether it was at the apex, along the sides, or in the interior of the triangle.

All of the cultures were then diluted up to the 250 c.c. mark.

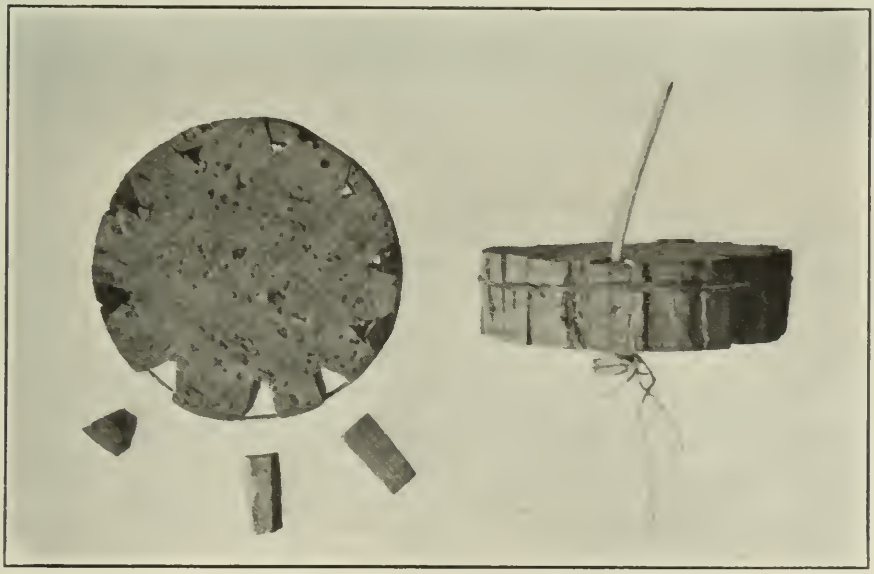
In this investigation, as already mentioned, the culture solution usually contained 25 parts per million of the aldehyde to be tested. The amount of this compound to be added to each culture

FIG. 6.



Method of germinating many thousand seedlings on perforated aluminum plates floated on the surface of water by means of a sealed glass tube raft in a porcelain-lined tank.

FIG. 7.



Method of mounting the seedlings in the notched corks.

bottle of 250 c.c. was therefore 6.25 milligrammes. Of the 250 c.c., 20 c.c. was already contained in the bottles in the form of the fertilizer salt solution. Therefore the solution with which the fertilizer salt solution in the bottles was to be diluted consisted of 6.25 milligrammes of the compound dissolved in 230 c.c. of pure water. A sufficient quantity of this strength of solution was prepared to fill the 66 bottles.

As a means of comparing the cultures grown in these solutions containing the aldehyde compound, it was necessary to put up cultures prepared in exactly the same way, except that pure water was used for dilution, as above mentioned.

In all of this work physiologically pure water was used. This was prepared by shaking ordinary distilled water with a highly absorptive carbon black, as described, which removes from the water any injurious property it may possess.

The culture solutions are now ready to receive the plants, which were thereafter grown in a greenhouse under suitable conditions.

In this work it was necessary to have a large number of seedlings of a uniform size. These were germinated on a perforated aluminum disc floated on the surface of a tank of water, as shown in Fig. 6. The seedlings were put in the culture bottles when about one inch high. The method of supporting them in the bottles by means of notched corks is shown in Fig. 7.

In analyzing the solutions the colorimetric methods described in Bulletin 31 of the Bureau of Soils (41) were used for the determination of phosphates, nitrates, and potash.

SALICYLIC ALDEHYDE.

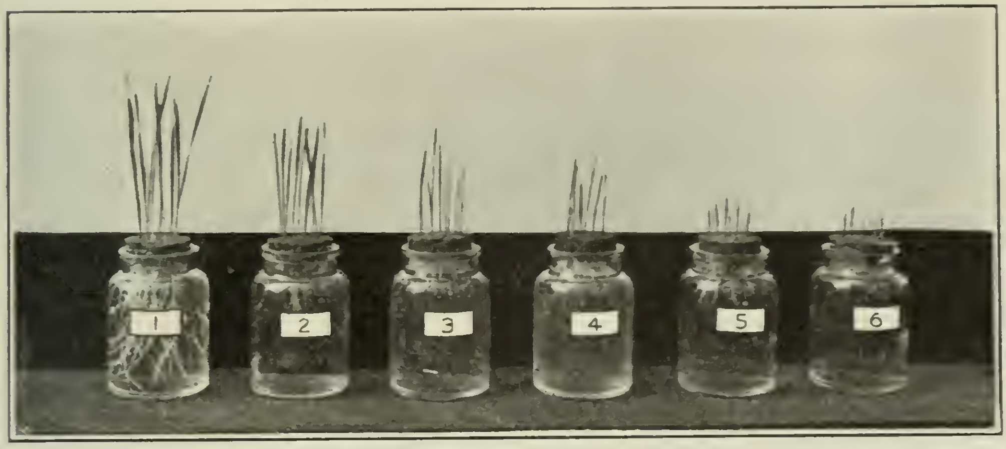
Salicylic aldehyde, $C_6H_4 <^{COH}_{OH}$, the first compound studied is orthohydroxybenzaldehyde. It is an aromatic aldehyde and is easily reduced from the corresponding alcohol, saligenin, $C_6H_4 <^{CH_2OH}_{OH}$, or oxidized to the corresponding acid, salicylic acid, $C_6H_4 <^{COOH}_{OH}$

Salicylic aldehyde occurs in several plants, in several species of Spiræa (18, 84), and in *Crepis fœtida* (83). It is also formed by the oxidation of salicin, a glucoside that occurs in many species of Salix and Spiræa. As pointed out in the previous section of this paper, it occurs in a number of soils, especially soils of low productivity. Its harmfulness to plants was reported in 1914(58).

Effect on Growth.

The effect of salicylic aldehyde was first studied by growing wheat in distilled water containing varying concentrations of the organic compound. Solutions were made containing 10, 25, 50, 100, and 200 parts per million of the aldehyde, and 10 wheat plants were grown in each culture for 10 days. The plants were killed in the three highest concentrations, while 25 parts per million reduced growth material, and even 10 parts per million reduced growth 31 per cent. The appearance of this series of plants on the sixth day is shown in Fig. 8.

FIG. 8.



Effect of salicylic aldehyde on wheat: No. 1, distilled water; No. 2, salicylic aldehyde, 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

Other plants to which this aldehyde proved harmful in aqueous solutions are corn, cowpeas, and cabbage. This experiment was made in a nutrient solution of calcium acid phosphate, sodium nitrate, and potassium sulphate, with and without aldehyde in varying concentrations. The plants grew in the solutions from May 20 to June 20, 1912; one plant was grown in each culture. Photographs of the cowpeas and corn are shown in Figs. 9 and 10. The green weight results taken at the end of the experiment are given in Table IV.

As seen by the figures in the table, the green weight was materially reduced by the aldehydes. Ten parts per million reduced the growth of the corn from 100 to 60, and in 200 parts per million, the highest concentration used, the corn made practically no growth.

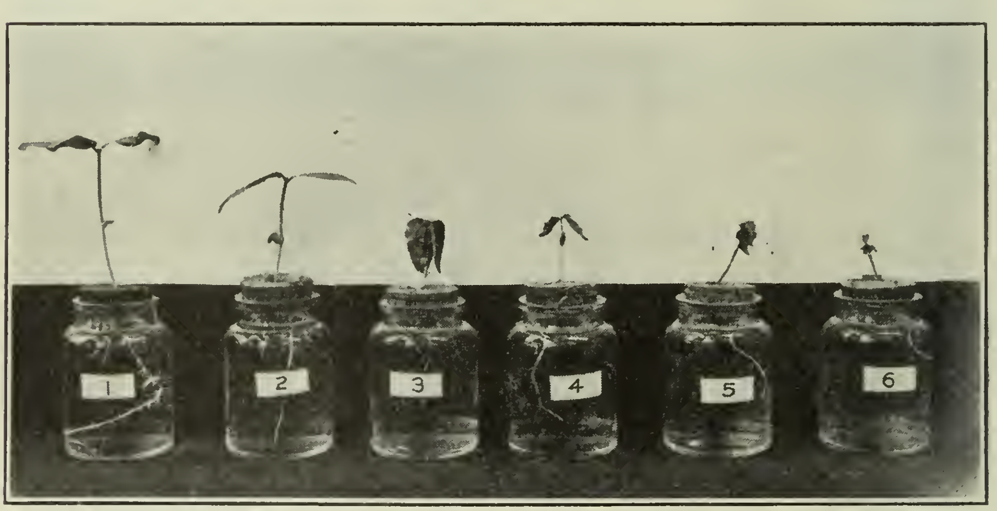
TABLE IV.

Effect of Salicylic Aldehyde on Corn and Cowpeas in a Nutrient Solution. Green Weight of Plants in Grammes.

Treatment	Corn		Cowpeas	
	Green weight	Relative growth	Green weight	Relative growth
Nutrient solution	1.00	100	1.35	100
Nutrient solution + 10 parts per million salicylic aldehyde	.60	60	1.35	100
Nutrient solution + 25 parts per million salicylic aldehyde	.60	60	0.70	51
Nutrient solution + 50 parts per million salicylic aldehyde	.21	21	.35	26
Nutrient solution + 100 parts per million salicylic aldehyde	.21	21	.20	15
Nutrient solution + 200 parts per million salicylic aldehyde	.10	10	.15	11

The cowpeas were also killed in the higher concentrations, while 10 parts per million was not harmful. Twenty-five parts per million, however, reduced growth from 100 to 51, as shown in the last column of the table.

FIG. 9.

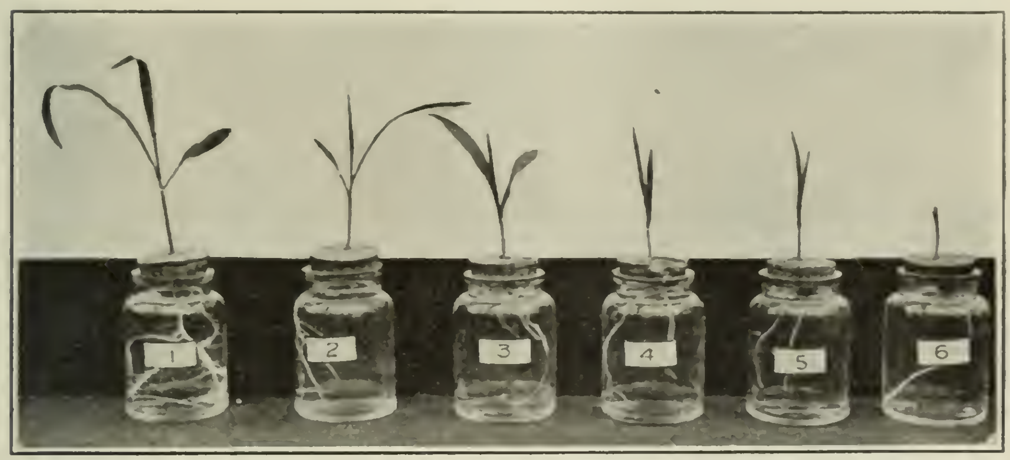


Effect of salicylic aldehyde on cowpeas: No. 1, nutrient solution; No. 2, salicylic aldehyde 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

In the experiment with young cabbage seedlings the green weights were not taken. Concentrations as high as 50 parts per million killed the young plants, and growth was materially reduced in 10 and 25 parts per million. It was evident that small amounts of salicylic aldehyde were quite harmful to the young cabbage plants.

These preliminary experiments with wheat corn, cowpeas, and cabbage seedlings show that salicylic aldehyde is very harmful to plants, in very small amounts in aqueous solutions, and that it is severely injurious and kills in amounts higher than 50 parts per million. The roots of all the plants, as well as the tops, were affected.

FIG. 10.



Effect of salicylic aldehyde on corn: No. 1, nutrient solution; No. 2, salicylic aldehyde 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5, 100 ppm.; No. 6, 200 ppm.

Effect in Solutions with Various Fertilizer Ingredients.

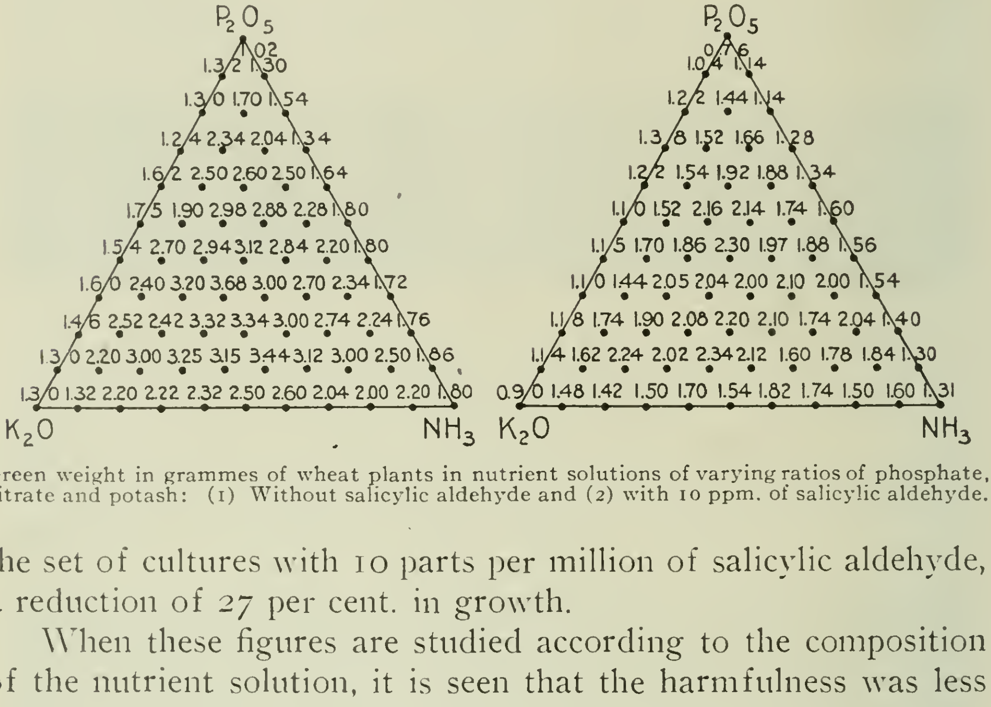
The effect of salicylic aldehyde on wheat plants was further studied by growing the seedlings in nutrient-culture solutions containing the ordinary fertilizer salts—calcium acid phosphate, sodium nitrate, and potassium sulphate. Some of the cultures contained the salts singly and some in combinations of two and three, the ratio varying in 10 per cent. stages, as already explained. The solutions were made 66 in number, according to the triangular diagram system. The salicylic aldehyde was used in concentrations of 10 parts per million. The experiment is especially interesting in that it shows the effect of certain of the fertilizer salts in changing the physiological effect of the aldehyde. The effect of the aldehyde on the metabolism of the plant was also studied by analyzing the culture solutions.

The plants grew in the solutions from May 15 to May 27, four changes of solutions being made during the experiment.

After several days it was noticeable that the salicylic aldehyde cultures were developing more slowly. Each of the cultures seemed affected, regardless of the composition or the proportion of the nutrient salts. The green weight of each culture without salicylic aldehyde is given in Diagram 1 and that of each culture containing the aldehyde in Diagram 2 of Fig. 11. The composition of each of these solutions, as to the ratio of the nutrient salts, can be determined by consulting Fig. 5.

By a comparison of the two diagrams it is seen that the green weights of the set containing the aldehyde are lower in almost every culture than the weights of the corresponding cultures without the aldehyde. The total weight of the 66 cultures without salicylic aldehyde is 149.5 grammes, against 109.7 grammes for the set of cultures with 10 parts per million of salicylic aldehyde, a reduction of 27 per cent. in growth.

FIG. 11.



Green weight in grammes of wheat plants in nutrient solutions of varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. of salicylic aldehyde.

When these figures are studied according to the composition of the nutrient solution, it is seen that the harmfulness was less in some groups of solutions than in others. There seemed to be a general tendency for more normal development in the cultures in the phosphate end of the triangle. This is brought out well if the weight of all the cultures which contain 50 per cent. and more of P_2O_5 are compared with those which contain 50 per cent. and more of NH_3, or with those which contain 50 per cent. and more of K_2O. All the high phosphate cultures are represented by the triangle marked by the points 1–16–21 of the diagram, Fig. 5. All the high nitrate cultures are represented by the triangle 21–61–66, and the high potash cultures are represented by the cultures in the triangle 16–61–56. By grouping the cultures thus an average result is obtained with the mainly phosphatic, mainly nitrogenous, and mainly potassic fertilizers. The sum of the 21 cultures in each group is given in Table V.

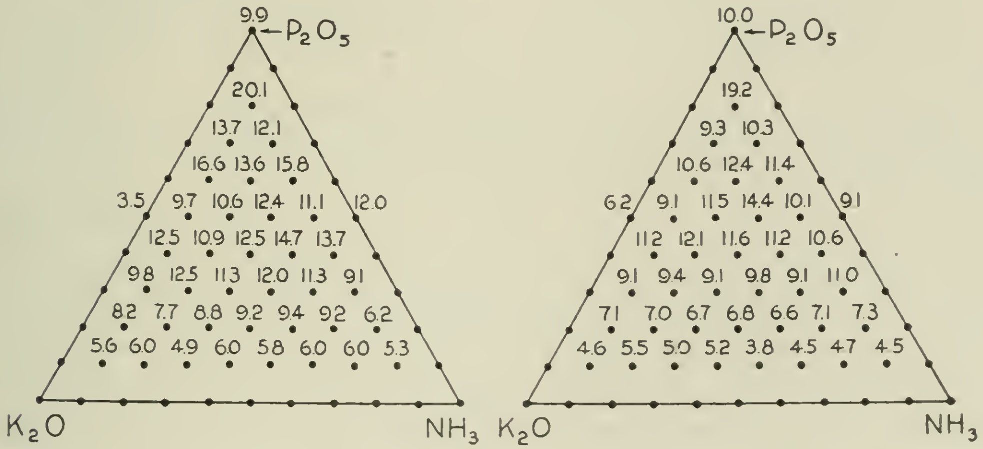
TABLE V.

Total Green Weights of the Mainly Phosphatic, Mainly Nitrogenous, and Mainly Potassic Cultures Without and With 10 Parts per Million Salicylic Aldehyde.

	Without salicylic aldehyde	With salicylic aldehyde	Per cent. decrease in salicylic aldehyde cultures
	Grammes	*Grammes*	
Phosphatic	39.61	31.74	20
Nitrogenous	49.36	36.11	27
Potassic	47.67	33.74	29

A comparison of the green weights shows that salicylic aldehyde reduced growth less in the phosphatic cultures than in the others. In the phosphatic cultures there was a reduction of 20 per cent. in growth, in the nitrogenous 27 per cent., and in the potassic 29 per cent.

FIG. 12.



Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

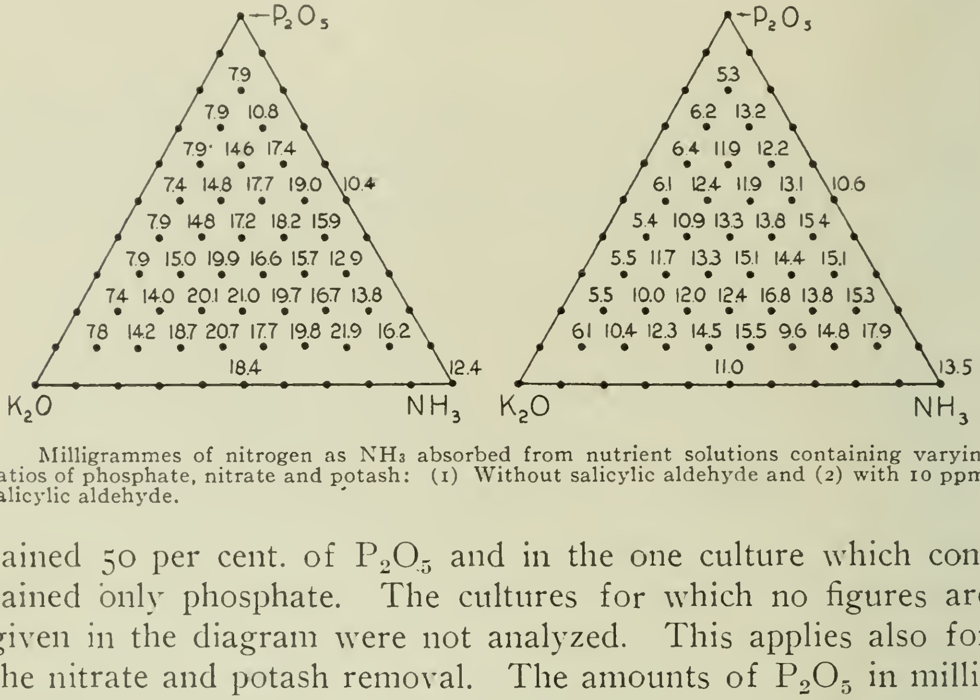
Absorption of Nutrient Salts.

As salicylic aldehyde has been shown to be harmful to growth in culture solutions containing nutrient salts, it will be interesting to study its effect on the removal of nutrients from the solutions during the growth of the plant.

As stated above, the concentration differences produced by the growth of the plants in the various cultures were determined by making an analysis for nitrates at the termination of every three-day change, and of phosphate and potassium on a composite of the solutions from the four changes. It is possible, therefore, to compare the results obtained in the normal cultures without salicylic aldehyde and in the cultures where 10 parts per million of salicylic aldehyde were present in the solution.

Phosphates.—The absorption of phosphates was determined only in those solutions in which the three constituents were present, as shown in Fig. 12, and in the two cultures which contained 50 per cent. of P_2O_5 and in the one culture which contained only phosphate. The cultures for which no figures are given in the diagram were not analyzed. This applies also for the nitrate and potash removal. The amounts of P_2O_5 in milligrammes removed from each culture without and with salicylic aldehyde are given in diagrams 1 and 2 of Fig. 12. The plants growing in the aldehyde cultures have removed slightly less phosphates than those in the normal cultures. The total absorption from the normal set was 395.7 milligrammes and for the aldehyde set 344.2 milligrammes. The salicylic aldehyde cultures absorbed 51.5 milligrammes less than the normal cultures.

Fig. 13.

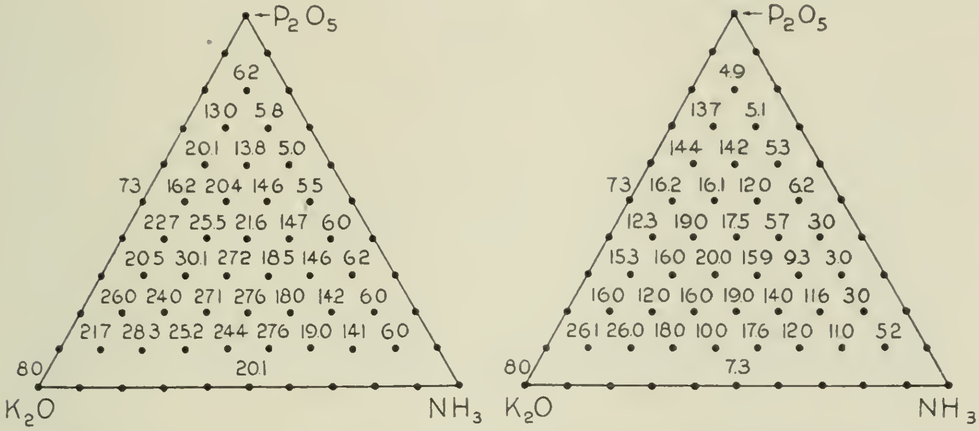


Milligrammes of nitrogen as NH_3 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

Nitrates.—An examination of the two diagrams of Fig. 13 will show that there was considerable difference of absorption of nitrates between the cultures without and with salicylic aldehyde. The total amounts of nitrate, stated as NH_3, removed from the total number of cultures analyzed during the course of the experiment were 578.3 milligrammes for the normal cultures and 454.9 milligrammes for the salicylic aldehyde cultures. The aldehyde cultures used 123.4 milligrammes less nitrate.

Potassium.—The amounts of potash, stated as K_2O, absorbed by the plants in the total number of cultures as shown in the diagrams of Fig. 14 were 627.6 milligrammes in the case of the normal cultures and 533.2 milligrammes for the cultures with salicylic aldehyde. As with the phosphate and nitrate, the salicylic aldehyde cultures absorbed less potash, there being a difference of 139.4 milligrammes in favor of the normal cultures.

FIG. 14.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

From the foregoing results it is seen that salicylic aldehyde in amounts as small as 10 parts per million is harmful to the growth of wheat in nutrient solutions. In regard to the composition of the nutrient solutions affecting the harmfulness of the aldehyde it might be said that an examination of the total green weights obtained in the case of the mainly phosphatic, the mainly nitrogenous, and the mainly potassic cultures shows that the least harmful effects are noted in the phosphatic group of cultures. This group as a whole shows a depression due to salicylic aldehyde of approximately 20 per cent. in growth, while the other two groups showed approximately 27 and 29 per cent. below the respective group of cultures without the aldehyde.

An examination of the above analytical figures shows a more nearly normal absorption of phosphate than of the nitrate or potash under the influence of the salicylic aldehyde. This would appear to be in harmony with the relatively lessened toxicity of the aldehyde in the mainly phosphatic nutrient solutions.

Effect of Manganese on the Action of Salicylic Aldehyde.

The effect of manganese on the harmfulness of salicylic aldehyde was studied in an experiment growing wheat plants in distilled water. The wheat seedlings were grown in culture jars holding 25 c.c. of pure distilled water. The plants grew for twelve days. The results are given in Table VI.

TABLE VI.

Effect of Manganese Sulphate On the Action of Salicylic Aldehyde in Distilled Water.

Treatment	Green weight *Grammes*
Distilled water	1.37
5 ppm. salicylic aldehyde	1.18
5 ppm. salicylic aldehyde + 1 ppm. manganese	1.32
5 ppm. salicylic aldehyde + 5 ppm. manganese	1.32
5 ppm. salicylic aldehyde + 10 ppm. manganese	1.50
10 ppm. salicylic aldehyde	0.87
10 ppm. salicylic aldehyde + 1 ppm. manganese	1.04
10 ppm. salicylic aldehyde + 5 ppm. manganese	1.57
10 ppm. salicylic aldehyde + 10 ppm. manganese	1.45
1 ppm. manganese	1.42
5 ppm. manganese	1.59
10 ppm. manganese	1.57

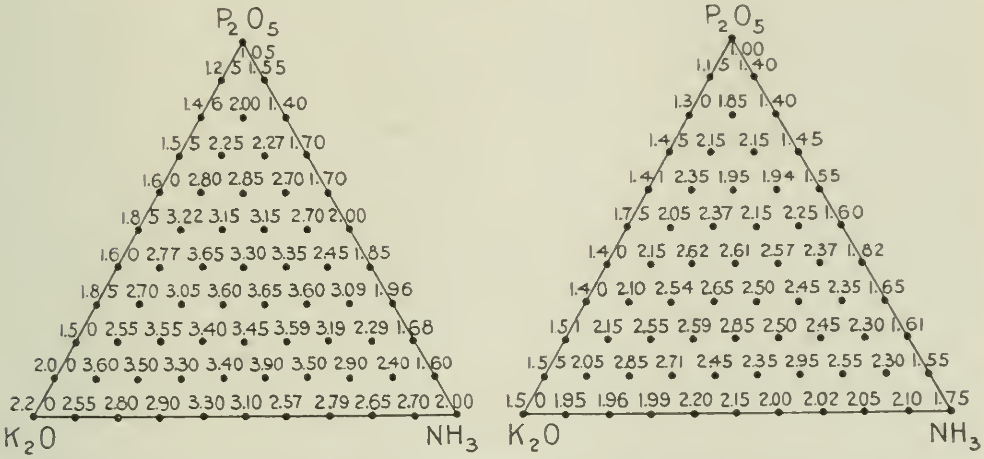
As seen from the green weight figures in the table, the salicylic aldehyde was harmful in distilled water in amounts of 5 and 10 parts per million. Manganese sulphate in amounts of 1, 5, and 10 parts per million of manganese overcame the effect of the aldehyde partly with the lower concentration of manganese and entirely with the larger amount.

Effect of Calcium Carbonate on the Action of Salicylic Aldehyde.

In order to study the effect of salicylic aldehyde under physiologically alkaline conditions, an experiment was made in nutrient-culture solutions containing calcium carbonate. The experiment was a duplicate of the one with the 66 nutrient solutions just recorded, except that 100 milligrammes of calcium carbonate was added to each culture in both the normal triangle and in the salicylic aldehyde triangle. Salicylic aldehyde was used in quantities of 10 parts per million. The plants grew from March 23 to April 4—12 days. The solutions were changed every three days. The green weights of the plants grown in solutions without and with salicylic aldehyde are given in the diagrams of Fig. 15.

These data show that salicylic aldehyde was harmful even in nutrient solutions containing an excess of lime. The total green weight of the 66 cultures in the normal set was 171.5 grammes, against 135.3 grammes for the set of cultures with salicylic aldehyde. In this case the growth was depressed 21 per cent. as an average of all the cultures. In the previous experiment, involving a large number of nutrient solutions without calcium carbonate, growth was reduced 27 per cent. by salicylic aldehyde used in the same concentration. While the aldehyde was harmful in the presence of lime, the experiment indicates somewhat that lime overcomes its effect to a slight degree.

FIG. 15.



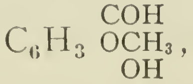
Green weight in grammes of wheat plants in nutrient solutions of varying ratios of phosphate, nitrate and potash with calcium carbonate: (1) Without salicylic aldehyde and (2) with 10 ppm. salicylic aldehyde.

The roots of the plants were not nearly as much stunted in the presence of calcium carbonate as they were in the experiment where no lime carbonate was used. The harmfulness of the aldehyde can in no way be attributed to any slight acidity it may possess.

When the cultures are grouped, as in the former set without lime, according to the composition of the solution, it is seen that salicylic aldehyde reduced growth in the 21 mainly phosphatic solutions (sub-triangle 1–16–21) 12 per cent., in the 21 mainly nitrogenous solutions (sub-triangle 21–61–66) 20 per cent., and in the 21 mainly potassic solutions (sub-triangle 16–61–56) 25 per cent. The salicylic aldehyde was again less harmful in the solutions with high P_2O_5 content.

The ameliorating effect of high phosphate containing nutrient solutions, together with the relatively high absorption of phosphates, indicates that phosphates have some antitoxic action on the harmfulness of salicylic aldehyde in solution cultures.

Vanillin.

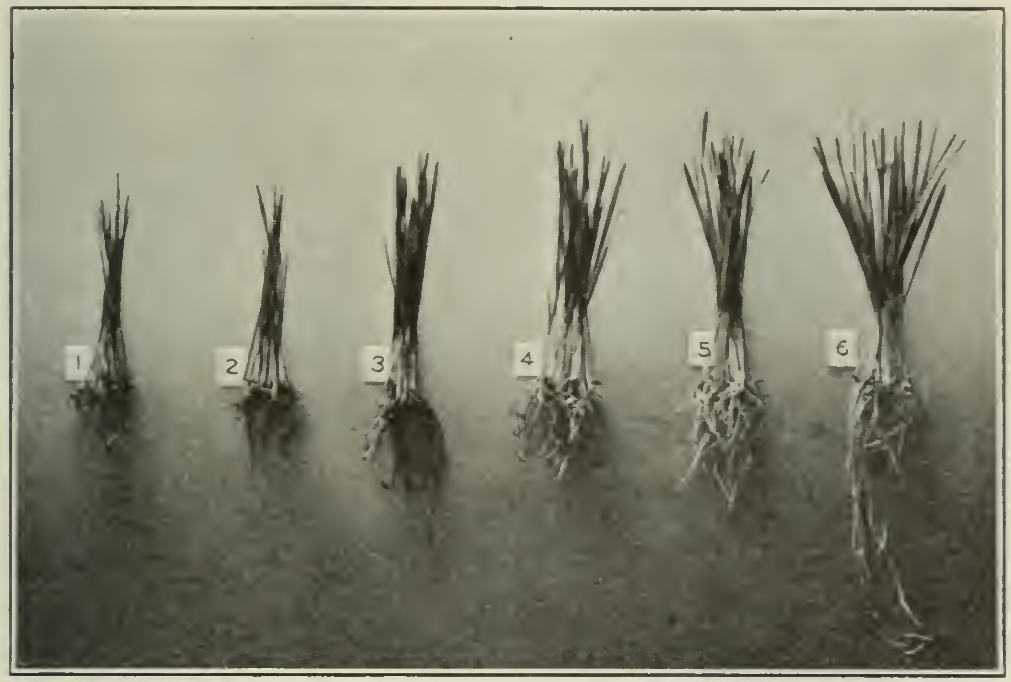
Vanillin,  $C_6H_3\begin{matrix}COH\\OCH_3\\OH\end{matrix}$, is an aromatic aldehyde, methyl protocatechuic aldehyde, and is the aromatic principle of the vanilla bean. Vanillin acid ($C_2H_8O_4$), a monomethyl-protocatechuic acid, may be formed by the energetic oxidation of the aldehyde vanillin. Vanillin has been found in seeds and roots of a number of plants. It has been reported in the seeds and roots of oats (36), in the seeds of the white lupine (12), in asparagus shoots (78), in raw beet sugar (39), in dahlia roots (35, 80), and in rotten oak wood (74). It has been found in a number of soils; its origin is thought to be from the decay of vegetable matter.

Effect on Growth.

Vanillin, then, has the characteristics of an aldehyde and, like the salicylic aldehyde, is toxic to plants, though to a less degree. Vanillin solutions were shown by Klebs to be fatal to the alga *Conferva minor* (26), and Reed and Williams (37) found that vanillin in 500 and 1000 parts per million reduced the growth and fixation of nitrogen by Azotobacter 28 and 57 per cent. respectively.

It has been found in solution cultures to be toxic to wheat seedlings, 500 parts per million being sufficient to kill. Plant roots are able to oxidize vanillin and become dark as a result of the oxidation. A slight stimulating effect was observed with very weak solutions (43, 52). In Fig. 16 are shown the effects of different concentrations of vanillin in distilled water on wheat plants. The harmfulness of the vanillin in water cultures is here shown, and it can be observed that the roots of plants grown in concentrations greater than 100 parts per million are stained a dark color as a result of the oxidation of the vanillin. The toxic effects of the vanillin were less marked upon the tops of the wheat plants than upon the roots, nevertheless the green weight of the tops of all the solutions was less than that of the tops of the controlled plants grown in distilled water. Work reported in 1911 shows that vanillin, an oxidizable substance, behaves quite differently in nutrient-solution cultures from quinone, a reducing substance (52, 53).

FIG. 16.



Effect of vanillin in distilled water on wheat seedlings: No. 1, vanillin 1000 ppm.; No. 2, 500 ppm.; No. 3, 100 ppm.; No. 4, 25 ppm.; No. 5, 1 ppm.; No. 6, distilled water.

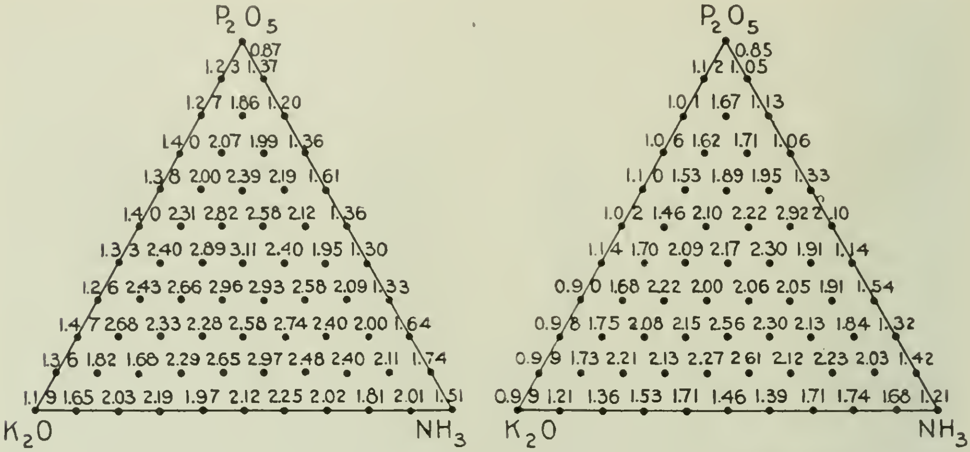
Effect in Nutrient Solutions with Various Fertilizer Ingredients.

In the experiment with vanillin in nutrient solutions the same number of cultures, 66 containing all the fertilizer combinations possible in 10 per cent. stages, was used as in the experiment with the salicylic aldehyde. The concentration of vanillin used was 50 parts per million. The duration of the experiment was from March 7 to March 19. The solutions were changed every three days, as in the salicylic aldehyde experiment already described, but no analyses of the solutions were made in this case. The green weights were, however, recorded, and are given for each culture in the diagrams of Fig. 17.

The effect of the vanillin was not so marked on the tops as on the roots, although in the region of better growth this also was not very prominent. The effect, even with 50 parts per million, was not so harmful as salicylic aldehyde. The region of greatest growth appeared to be shifted toward the nitrogen end of the triangle.

The total growth in the normal set of cultures was 133.5 grammes, against 111.5 grammes for the set of cultures containing the vanillin. This is a reduction of 26 per cent. The growth in the cultures respectively high in phosphate, nitrate, or potash is of paramount interest. This grouping of the cultures as explained in the salicylic experiment is shown in Table VII.

FIG. 17.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without vanillin and (2) with 50 ppm. of vanillin.

TABLE VII.

Total Green Weight of the Mainly Phosphatic, Mainly Nitrogenous, and Mainly Potassic Cultures, Without and With 50 Parts Per Million of Vanillin.

Culture solutions	Without vanillin	With vanillin	Per cent. decrease in vanillin cultures
	Grammes	*Grammes*	
Phosphatic	37.8	31.9	15
Nitrogenous	42.8	37.8	12
Potassic	40.7	33.2	18

It will be observed that vanillin depressed growth least in the cultures high in nitrate, a result which is in harmony with previous observations on the toxicity of vanillin and its behavior with nitrate.

Vanillin has reducing properties; that is, it is readily oxidized.

It has an inhibiting effect on root oxidation and on root growth in general. Sodium nitrate and calcium carbonates, which promote oxidation in plants and soils, ameliorate the harmfulness of vanillin. The action of fertilizers on the two aldehydes thus far reported is quite different. The harmful effects of salicylic aldehyde in nutrient solutions are lessened by phosphates, and the harmfulness of vanillin in nutrient solution is lessened by sodium nitrate.

THE EFFECT ON COWPEAS IN NUTRIENT SOLUTIONS OF DIFFERENT COMPOSITIONS.

An experiment growing cowpeas in nutrient solutions was made in which the effect of vanillin was studied. The solutions were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, used singly and in combinations. It was found that in some of these nutrient solutions the vanillin was more harmful than in others. Culture jars holding 250 c.c. of solution were used, and two cowpea plants were grown in each jar. The plants were germinated in sand, and when about 1 inch high were put in the nutrient solution. The culture solutions, as stated above, were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, in amount of 80 parts per million total of P_2O_5, NH_3, and K_2O. These solutions were changed every fifth day; the old solutions were replaced by new four times during the experiment. They were analyzed to determine the amount of phosphate, nitrate, and potash removed by plants. In this way the effect of vanillin on the metabolism of plants was studied. The peas grew for 21 days, from June 17 to July 8. The results are given in Table VIII. The composition of the culture solutions is given in the second, third, and fourth columns. The green weights of the plants grown in the solutions without vanillin are given in the fifth column, and with 100 parts per million of vanillin in the sixth column. The absorption of the nutrient salts is given in the remainder of the table.

The green weight was reduced by the vanillin in each culture except No. 5. When the cultures are grouped as in the table, according to their composition, it is seen that the vanillin is least harmful in those cultures which are composed principally of nitrates. Cultures Nos. 1 to 4 are composed principally of phosphate; Nos. 5 to 8 principally of nitrates, and Nos. 9 to 12 prin-

TABLE VIII.

Growth of Cowpeas in Nutrient Solution With and Without Vanillin (100 p.p.m.). June 17 to July 8.

No.	Composition of culture solution			Green weight of cultures		Nutrient absorbed					
						P_2O_5		NO_3 stated as NH_3		K_2O	
	P_2O_5	NH_3	K_2O	without vanillin	with vanillin	without vanillin	with vanillin	without vanillin	with vanillin	without vanillin	with vanillin
	p.p.m	*p.p.m.*	*p.p.m.*	*grams*	*grams*	*m.g.*	*m.g.*	*m.g.*	*m.g.*	*m.g.*	*m.g.*
1	80	0	0	1.37	1.10	16.0	13.2	.....	.....	.....	.....
2	64	8	8	3.57	2.50	15.3	13.1	8.0	7.5	4.9	4.0
3	48	16	16	4.87	3.97	12.1	7.3	12.2	8.9	12.2	6.4
4	32	24	24	5.37	3.55	10.7	7.1	14.6	13.2	17.5	17.5
				15.18	11.12						
5	0	80	0	2.20	2.70	....	....	25.5	24.6	.....	.....
6	8	64	8	3.52	3.40	1.8	0.6	15.3	14.6	3.5	2.3
7	16	48	16	5.02	4.95	3.4	3.4	12.9	16.8	12.0	8.0
8	24	32	24	4.55	4.30	10.4	7.9	17.4	13.1	12.0	15.0
				15.29	15.35						
9	0	0	80	1.85	0.80	....	....	.....	.....	30.2	8.0
10	8	8	64	4.67	4.05	2.1	3.8	8.0	7.7	25.6	23.0
11	16	16	48	5.47	3.70	3.8	4.5	12.1	11.8	24.0	19.0
12	24	24	32	5.95	3.00	8.7	5.3	16.3	10.8	28.5	11.0
				17.94	11.55						
Total....................				48.41	38.12	88.3	66.2	142.3	129.0	170.4	114.7
Percent. decrease in vanillin culture . .					21		21		10		33

cipally of potassium. The total green weight of the high phosphate cultures (Nos. 1 to 4) was 15.18 grammes in the solutions without vanillin and 11.12 grammes with vanillin. In the high nitrate cultures (Nos. 5 to 8) the weight without vanillin was 15.29 grammes, against 15.35 grammes for the cultures with vanillin. In the high potash cultures (Nos. 9 to 12) the weight without vanillin was 17.94 grammes, against 11.55 grammes for the cultures with vanillin. It is apparent that in the solution composed principally of nitrate the vanillin had practically no effect, and in culture No. 5, composed of all nitrate, the growth in the vanillin culture was larger than in its control.

The absorption of salts was also less from the solutions containing vanillin than from their controls without vanillin. The absorption of each nutrient element for each culture is given in the table. Considering all the cultures, the phosphate absorption was reduced 21 per cent., the nitrate 10 per cent., and the potash 33 per cent. The absorption of nitrate was less interfered with by the vanillin than either phosphate or potassium.

The results with cowpeas are in harmony with those with wheat seedlings, where it was shown that the harmfulness of vanillin was very slight in solutions high in nitrate content, and that its effect was less in cultures composed principally of nitrate than in cultures composed principally of phosphate or potassium (52, 53). The roots of plants have an oxidizing power, which is increased by nitrate fertilizers (45). Vanillin is changed or even destroyed by oxidation. This compound, when used in nutrient solutions containing a high percentage of nitrates, is probably changed, and does not remain as such to have its effect on plant growth.

Effect of Manganese on the Physiological Action of Vanillin.

The effects of manganese on the harmfulness of vanillin were studied in an experiment growing wheat plants in distilled water. The wheat seedlings were grown in culture jars holding 250 c.c. of pure distilled water. Manganese sulphate was used in amounts of 1 and 5 parts per million of manganese. The plants grew 12 days. The results are given in Table IX.

TABLE IX.

Effect of Manganese Sulphate On the Harmful Action of Vanillin in Distilled Water.

Treatment	Green weights *Grammes*
Distilled water	2.18
100 ppm. vanillin	1.60
100 ppm. vanillin + 1 ppm. manganese	2.03
100 ppm. vanillin + 5 ppm. manganese	1.90
1 ppm. manganese	2.20
5 ppm. manganese	2.24

The harmful effect of vanillin was here partly overcome by manganese used in small amounts. The oxidizing power of the plant roots was determined in the different culture solutions by the method described in Bulletin 56, Bureau of Soils (45), and Bulletin 42 of the U. S. Department of Agriculture (71). The oxidation was lessened in the vanillin culture, but was increased in the solution where manganese was used, which is in harmony with the growth in these solutions.

Manganese increases the oxidizing power of plants in certain soil extracts (59), as well as increases the oxidation of certain soils.

In a later section of this paper are given experiments bearing on the effect of manganese in soils to which vanillin and salicylic aldehyde were added. It is there shown that manganese destroyed the effects of these aldehydes to a certain extent. All these results point to the fact that manganese, through stimulating oxidation, can aid in the destruction of such harmful organic substances as aldehydes capable of ready oxidation.

BENZALDEHYDE.

Benzaldehyde, C_6H_5-COH (oil of bitter almonds), is formed, together with glucose and hydrocyanic acid, by the decomposition of amygdalin, a glucoside which is found in bitter almonds, peach-stones, and several other vegetable substances. Benzaldehyde oxidizes readily to benzoic acid, C_6H_5COOH, and unites with hydrogen to form benzyl alcohol, $C_6H_5CH_2OH$. The relations between the three substances are like those between any primary alcohol and the corresponding aldehyde and acid, as shown by the formulas:

$C_6H_5.CH_2OH$;	$C_6H_5.COH$;	$C_6H_5.COOH$
Benzyl alcohol	Benzoic aldehyde	Benzoic acid

Effect on Growth in Nutrient Solutions with Various Fertilizer Ingredients.

The experiments with benzaldehyde in nutrient-culture solutions showed it to be very harmful to wheat plants in relatively small amounts. A complete triangle set of solutions, composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, used singly and in combinations of two and three salts in 10 per cent. stages, as already described, was used. In this experiment the benzaldehyde was used in concentrations of 25 parts per million. Four changes of solutions were made during the experiment. The plants grew in the solutions from February 17 to March 1, 1916. The green weights of the individual cultures are given in the diagram of Fig. 18.

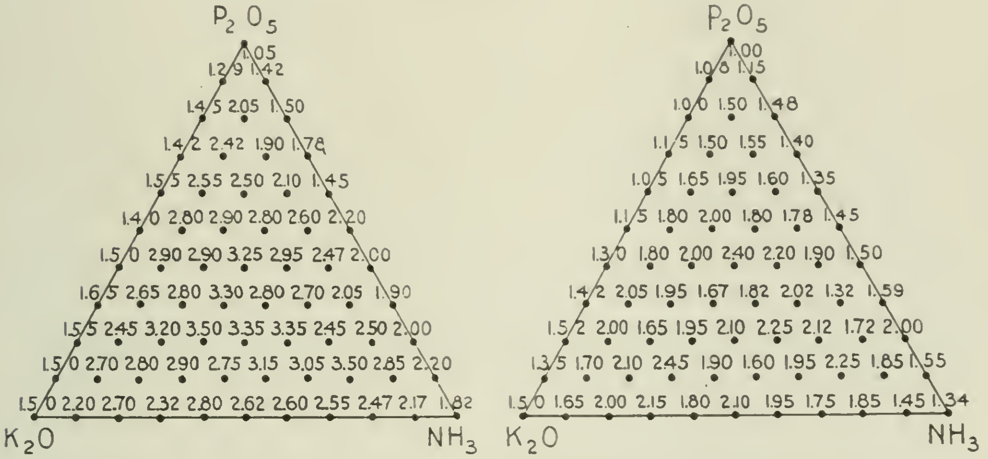
It is seen, by comparing the weights of the cultures without the aldehyde with the corresponding culture which contains the aldehyde, that in every case except one the aldehyde culture is smaller.

The total weight of the entire set of cultures in the triangle without benzaldehyde was 163.2 grammes, against 113.0 grammes for the set with 25 parts per million of benzaldehyde. This is a reduction of 30 per cent. in growth.

When the solutions are grouped according to their composition, it is seen that the 21 mainly phosphatic cultures—that is, those within the triangle marked by the points 1–16–21, Fig. 5—produced as a total 41.1 grammes green weight for the normal set and 30.5 grammes green weight for the benzaldehyde set, a reduction of 26 per cent.

The mainly nitrogenous cultures—that is, those solutions within the triangle marked by the points 21–61–66—produced 52.5 grammes green weight in the normal set and 37.5 grammes in the benzaldehyde set, a reduction of 29 per cent.

FIG. 18.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

The mainly potassic cultures—those solutions within the triangle marked by the points 16–61–56—produced 50.5 grammes green weight in the normal culture and 37.5 grammes in the benzaldehyde cultures, a reduction of 25 per cent.

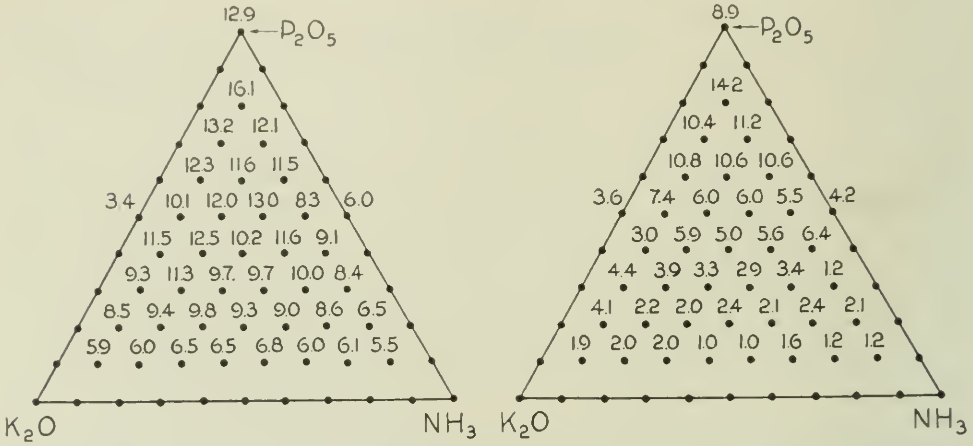
The depression of growth by benzaldehyde in the mainly phosphatic solutions and mainly potassic solutions was practically the same—in the former growth was depressed 26 per cent. and in the latter 25 per cent. The aldehyde was, however, somewhat more harmful in the highly nitrogenous solutions; in this case growth was reduced 29 per cent.

A second experiment with benzaldehyde in a complete set of nutrient solutions was made, in which the aldehyde was used in concentrations of 50 parts per million. With this concentration the aldehyde proved extremely harmful. There was an average reduction of all the solutions of 53 per cent.

Absorption of Nutrient Salts.

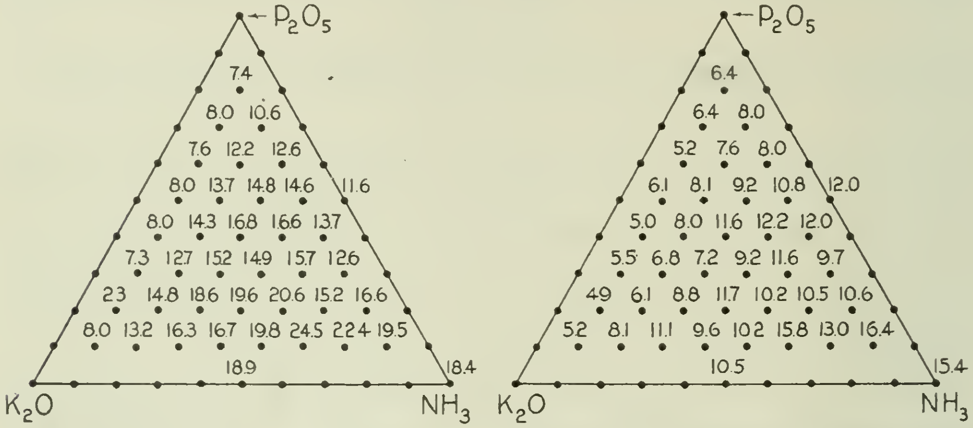
Phosphates.—The absorption of phosphates was much less in the 25 ppm. benzaldehyde set than in the normal set of cultures.

FIG. 19.



Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

FIG. 20.



Milligrammes of NH_3 as nitrate absorbed from nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

The amount, expressed in milligrammes, of P_2O_5 absorbed from each solution analyzed is given in the diagram of Fig. 19.

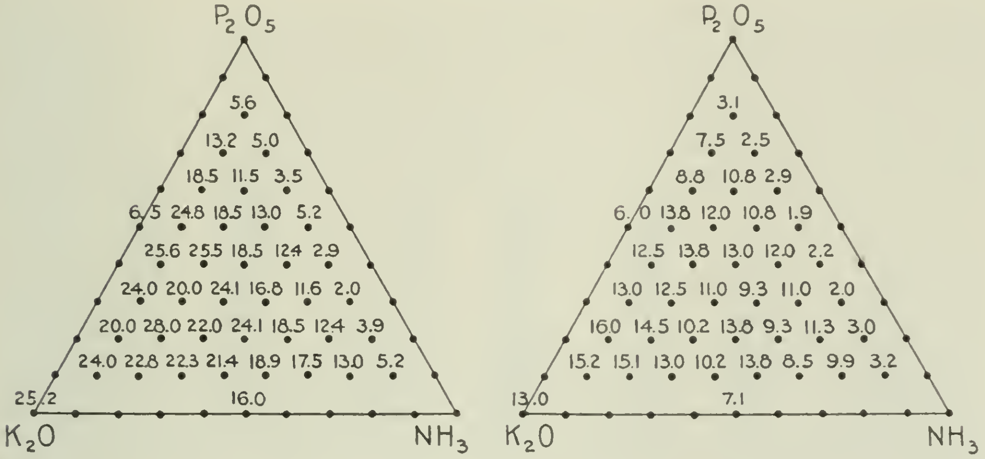
The total amount of P_2O_5 absorbed by the set of normal cultures was 366.2 milligrammes, and by the benzaldehyde cultures only 183.6 milligrammes, a reduction of 50 per cent.

Nitrates.—The absorption of nitrates was also less in the benzaldehyde cultures than in the normal cultures. This is true of almost every corresponding culture of the two sets, as will be shown by examining the diagrams of Fig. 20, which gives the absorption of each culture.

The normal set of cultures removed 574.5 milligrammes of NH_3 as nitrate, and the benzaldehyde set 364.1 milligrammes, which is a reduction of 37 per cent.

Potassium.—As with the phosphates and nitrates, there was also less potash removed from the benzaldehyde set of solutions than from the normal set. The percentage decrease, however, was not quite so large. The absorption of each culture analyzed is given in the diagram of Fig. 21. The normal set of solutions absorbed a total of 378.7 milligrammes of K_2O, and the benzaldehyde set a total of 379.4 milligrammes. This is a reduction of 35 per cent.

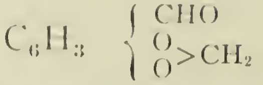
FIG. 21.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without benzaldehyde and (2) with 25 ppm. benzaldehyde.

The phosphate absorption was reduced 50 per cent. by benzaldehyde, the nitrate 37 per cent., and the potash 35 per cent. Thus it is seen that the absorption of potash is more normal than that of phosphate, and slightly more so than that of nitrates. In this connection it is interesting to note that the growth was slightly more normal in the mainly potassic solutions. The differences, though slight, indicate that potassium alters somewhat the physiological effect of this aldehyde.

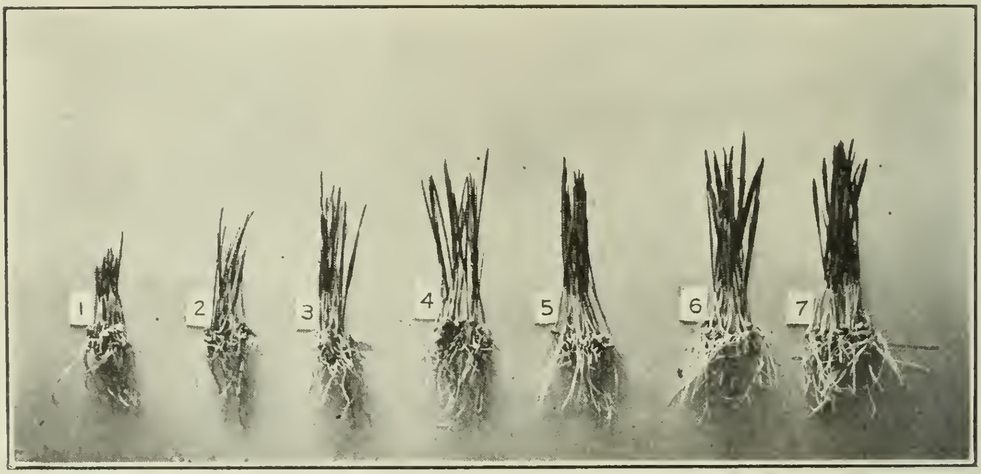
HELIOTROPINE.

Heliotropine or piperonal,  $C_6H_3\begin{cases}CHO\\ \left.\begin{matrix}O\\ O\end{matrix}\right>CH_2\end{cases}$ is the aldehyde of piperonylic acid. It possesses the odor of heliotrope and is found in the flowers of *Nigritella suaveolens* (78). It has not specifically been found as a soil constituent.

Effect on Growth.

Heliotropine was found to affect the growth of wheat plants in distilled water very markedly. The tops of the plants were affected more than the roots. The effect of this aldehyde on wheat plants is shown in Fig. 22. Here it is seen that the roots are almost normal, even in the highest concentration, while the tops are much reduced in growth in a concentration of 25 parts per million.

FIG. 22.



Effect of heliotropine in distilled water on wheat seedlings: No. 1, heliotropine 1000 ppm., No. 2, 500 ppm.; No. 3, 100 ppm.; No. 4, 25 ppm.; No. 5, 10 ppm.; No. 6, 1 ppm.; No. 7, distilled water.

Effect in Solutions with Various Fertilizer Ingredients.

The effect of the heliotropine on wheat seedlings was also studied in nutrient culture solutions, in which the triangular system of 66 solutions was used. The heliotropine was used in concentrations of 25 parts per million. The details of the experiments were the same as those described in the experiment with salicylic aldehyde and vanillin. The experiment was conducted from May 15 to May 27, 1916; four changes of solutions were made.

(To be Continued.)

ON THE LUMINESCENCE DUE TO RADIO-ACTIVITY.*

BY

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The luminescence produced by irradiating zinc sulphide and other substances with the rays from radio-active compounds has long been an object of interest. However, quantitative measurement of the brightness with such luminescent bodies has very rarely been made, and, in fact, it has been only in the last two or three years that definite quantitative comparisons were made between the so-called self-luminous paints that are now extensively employed for various military purposes.

In case of the self-luminous zinc sulphide paints, the brightness depends upon the amount of the radium elements present per gramme of the zinc sulphide. This is true for a given specimen of zinc sulphide and a given mode of treatment of it. For the intensity of luminescence attained is likewise dependent to a very great degree upon the purity of the zinc sulphide and upon its treatment. We have found this to be the case also with the specimens of self-luminous materials, some of whose characteristics are described below.

It is well known that the self-luminous substances that are commonly obtained on the market under the name of radium paints have a definite life. The brightness of them decreases with age, due not alone to the fact that all radio-active elements are decaying, but chiefly due to the fact that the zinc sulphide changes its form, so that it ceases to give the same intensity of light for the same intensity of stimulus.

In case of all the self-luminous paints containing any one of a number of radio-active elements, it is the α-rays which cause the emission of most of the light. In some of these compounds the light caused to be emitted by a single α-ray may be seen. The classical illustration of this is in the Crookes spinthariscope, where polonium or radium is the source of α-particles and zinc sulphide is the luminescent substance viewed with a lens. We have found a large number of substances which show the scintillations plainly. In the substances described below these scintillations are easily seen when the material has been properly prepared.

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* Communicated by Doctor Karrer.

After the luminescence of zinc sulphide has been decreased by age there is no known simple operation which will rejuvenate it, so that it may continue to luminesce throughout the life of the radio-active element.

Radium bromide, however, can be rejuvenated by heating. The fact that radium salts that are luminous may be rejuvenated by recrystallization when their luminosity has decreased has been known for some time and holds for all radio-active salts, and also that such salts become non-luminous when allowed to absorb moisture from the air and become luminous again when dried out. In case of autunite, drying seems to decrease the luminosity.

It has been known for some time that certain salts, such as barium platinocyanide, may be somewhat revived by heating when allowed to become exhausted under α-ray bombardment. The fact that radium bromide is so markedly rejuvenated by heating alone was independently observed by one of us.[1]

No quantitative data have been placed upon record such as we have attempted to give in this paper, where we purpose to describe some of these properties of self-luminous materials and, in particular, of radium bromide, which exhibits them very markedly.

Freshly prepared radium bromide is feebly luminous while in the solution, becoming more luminous after removal from the liquid and after drying by gentle heating. A tube of radium bromide so prepared will decrease in brightness with time, as self-luminous materials are wont to do, and if it contains a large amount of radium it will have decreased materially in brightness in a few days or even hours.

Then let us heat the tube by resting it upon an iron plate supported over a Bunsen flame. The tube will momentarily remain of the same brightness, so far as one can judge—probably actually decrease for a moment—then it will very suddenly flash up to a brightness sometimes comparable to its original brightness.

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[1] D. H. Kabakjian, paper before the Physics Faculty, May, 1917.

This flash is very momentary, and the brightness steadily and rapidly decreases thereafter until the tube is no longer luminous. The time which elapses between the commencement of the flashing to total decay is dependent upon the rate of heating to the necessary temperature. In our small tubes it was only a matter of a few seconds.

If now the tube be allowed to cool to room temperature, it will again become luminous with a brightness gradually increasing until room temperature is reached. If the tube be allowed to remain at room temperature, its brightness will have again materially decreased after several days, when the same cycle may be gone through again. These operations may be repeated indefinitely, so far as our experience with these tubes shows. There is at present no evidence that the end-products, for instance, of the decomposition of the radio-active element itself can materially affect the property to luminesce.

After heating, the salt is white in reflected sunlight, with only a trace of the yellowish tint. In time this color changes to a dark, almost black, having in it a bluish or purplish tint, due to the discoloration of the glass. In several tubes we have had very slight evidence that the granularity of the salt also changes.

The discoloring of the substance and behavior after heating indicate that the property to luminesce is dependent upon some molecular structure of the salt, and that, due to the process of radiating energy or incident to this manner of stimulus, this structure is destroyed.

The light emitted by the substance turns more greenish-blue with age, being quite white initially. We have now in progress experiments which will elucidate these changes in the spectral distribution of the energy, and elucidate somewhat the phenomenon of flashing up and of the discoloration of the salts and of the glass. The data will be given in a paper in the near future.

Though these are the salient and most obvious features regarding the spectrum of these substances, there are certain other very fleeting variations in the color of the light. During the flashing up the color becomes a very yellowish, then changes more green. On cooling, also, a similar variation takes place. A very yellowish hue changes into a bluish, and subsequently more and more white with decrease of temperature. Sometimes several flashes may occur on heating. This flashing up affords an admirable way to show the propagation of a heat wave through a solid.

Naturally it is of interest to inquire how these substances would behave at a temperature below room temperature. We have as yet only qualitative data to present on this point. However, lowering of the temperature below normal room temperatures does not have so striking effects as described above for higher temperatures.

If a tube of radium barium bromide which has been previously heated to a temperature of 400–500° C. is immersed in liquid air, the brightness of the salt undergoes probably a slight decrease, but otherwise no change is observed. If, after remaining in the liquid air for a few minutes, the tube is taken out and allowed to reach the room temperature gradually, the salt remains at its original degree of brightness for a few seconds, then suddenly it flashes up, reaching a brightness many times the original brightness, followed by a quick fall to a level below the original brightness. A repetition of this phenomenon may take place on a smaller scale before the tube reaches equilibrium. Three such successive oscillations with constantly decreasing amplitudes have been observed under favorable conditions.

These observations we hope to repeat quantitatively.

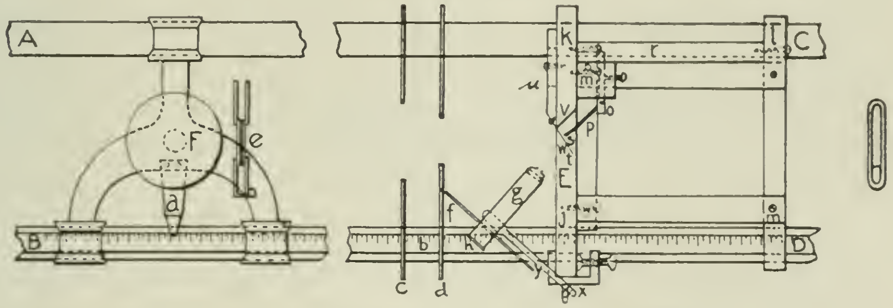
The phenomenon of flashing up is undoubtedly connected with the phenomenon of thermo-luminescence which glass shows after having been subjected to the rays from radium. However, two flashings have not been observed by us in glass alone, a large number of specimens of which have been examined in this respect. The flashing appears just below temperature of dull red iron. The discoloration also begins to disappear at about the same temperature. At dull red heat the purple discoloration, even though very intense, will disappear in a few minutes. A thick capillary tube which had been very much discolored became clear after heating for about 15 minutes at 250° C. The discoloration is not essential to the phenomenon of flashing. In fact, the intensity or quantity of the flash seems in some cases to be quite independent of the degree of discoloration. Fused quartz will show thermoluminescence when there are no indications whatever of discoloration.

The experimental set-up is shown in Fig. 1, where a horizontal sectional view is represented of a photometer bar equipped for the present investigation. *AC* and *BD* are bars upon which the carrier for the reference lamp *F* is mounted. The rays of light from the lamp *F* fall upon a celluloid card *t*, which is pierced with a small hole *w*, about 1 mm. in diameter, through which the luminescent surface *s* may be viewed. The card *t* and the luminescent surface *s* are observed through the telescope *g*, magnifying about two and one-half times.

The card of celluloid *t* is mounted upon an upright board *E*, half of which has been cut away, and the half *wk* remains. This board is held secure by a frame *jmlk* with a brace at *r*; *p* and *o* are adjustable rods to support the tube *s*. The tube is shown in Fig. 2 (3 mm. × 18 mm.).

c, *d*, and *f* are screens; *e* the color screen, attached to the carrier for the lamp and very close to the lamp. The position of the lamp is read by means of the index *a* on scale *b*. The lamp is a point-source tungsten (100-watt, 110-volt). The intensity of the light falling upon the screen *t* is calculated from the inverse square relation. This was tested for our lamp when supplied with the screens used.

Figs. 1 and 2.



Photometrical set-up for comparing brightness of luminescent substances, and, at extreme right, tube containing radium salt.

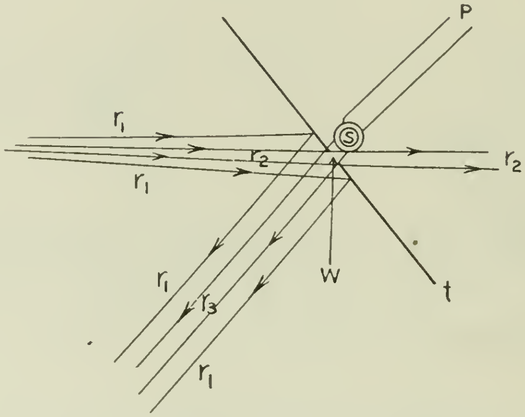
The manner of mounting the tubes under observation and the relative position of them are shown in an enlarged view of Fig. 3. The tube *s* was attached in a groove in the end of the rod *p* by means of soft wax. No rays direct from the standard lamp can fall upon the tube. This point is particularly important when self-luminous paints containing zinc sulphide are observed. The effects of an exposure may last longer than a day. Radium bromide is not sensitive to ordinary light.

The perforation at *w* in the celluloid card could preferably be made larger. It was adapted in the present case to the small samples of the radium salts available. The celluloid disc was coated with magnesia oxide. Its coefficient of reflection was 70.9 per cent. This was determined by means of an illuminometer mounted in the place of the observing telescope *g*.

The samples of radium bromide and of radium chloride were freshly prepared and sealed. In most instances the observations were made within the first three weeks after preparation.

The luminescent materials to which the curves refer were of unknown concentrations. The amount of them was in every case very minute and in some instances adhering to the glass walls, so that determination of the percentage of radium would be very difficult. Knowing the history of these preparations, however, we can state the approximate composition in the description of them.

FIG. 3.



Celluloid disc and manner of placing tube.

The tubes which are associated with the curves, Figs. 4, 5, 6, 7, and 8, were heated merely by resting them upon an iron plate heated by a Bunsen flame to a very dull red.

In the majority of cases the slopes of the curves are not intended to represent the rate of decay of luminescence accurately. Only in cases where a sufficient number of observations were taken can the curve be relied upon, such as the two in Fig. 4. All observations or means of several observations are indicated in the curves. One of the objects of this work was to ascertain whether the materials could be repeatedly subjected to heating and maintain something like the initial brightness. The curves show that there is some uniformity, as much as we may expect, under the crudely controlled conditions under which these experiments were performed. It is the last series of materials recorded in this paper that we are observing under more accurately controlled conditions.

In Fig. 4 are plotted the observations on a tube containing radium bromide and barium bromide. The radium constituted about 30 per cent. of this material. The decay of its brightness was very rapid. The curve with the crosses was obtained soon after the preparation of the salt, while the curve with the dots was obtained fourteen days after the last observation on the curve with the crosses was made. This sample of radium bromide was contained in a small quartz tube. The quartz tube became brittle and easily broke, so that observations with it were stopped. If the ordinates are divided by 40 they represent approximately millilamberts.

FIG. 4.

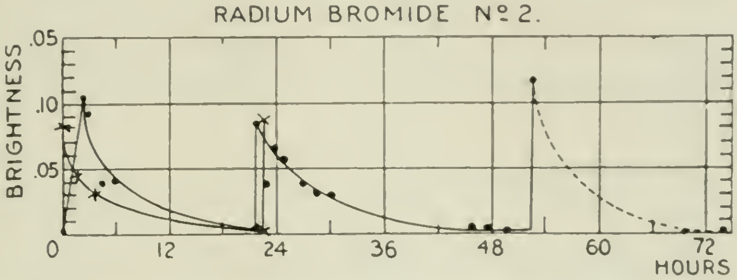
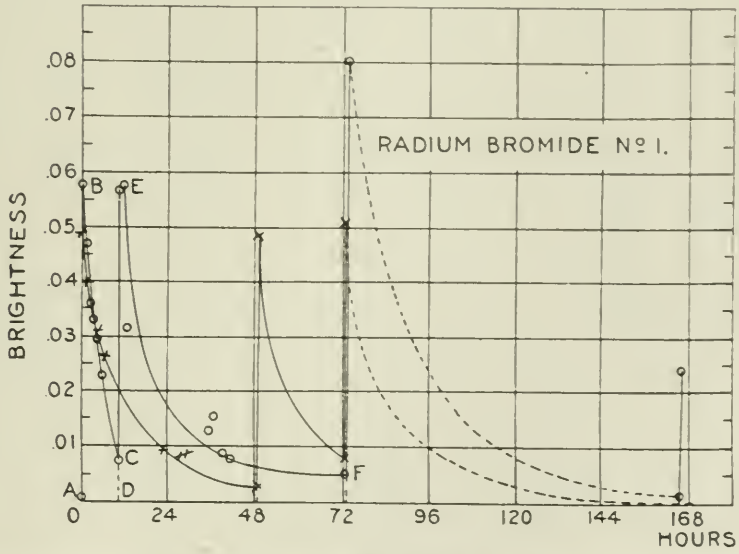


FIG. 5.



In Fig. 5 a similar series of observations is recorded for a preparation having a concentration of probably one-half that of the previous tube. The crosses denote observations made soon after the preparation of the tube, while the circles denote observations begun after fourteen days had elapsed since the last observation marked by a cross had been made. The last observation is lower than the similar observation after heating, because the heat-

FIG. 6.

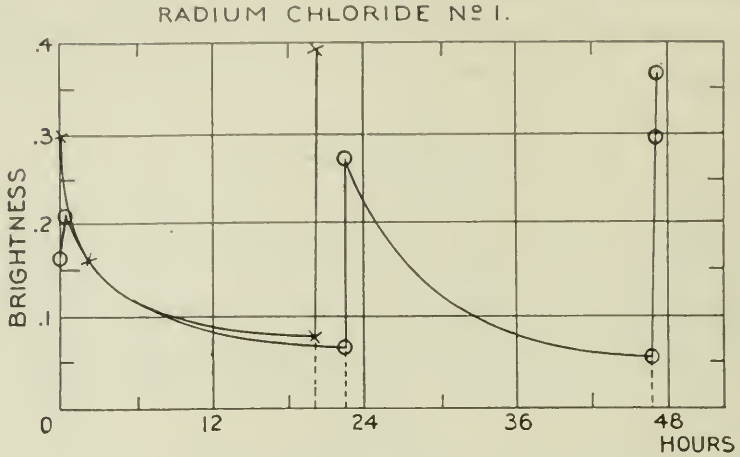
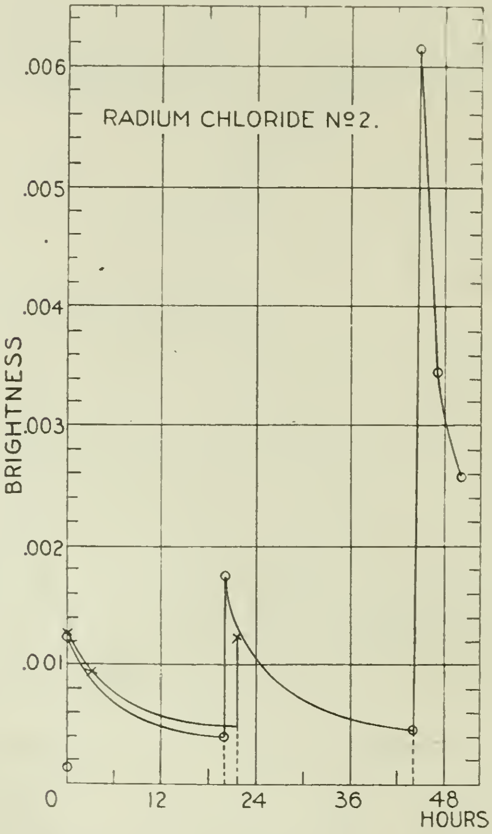


FIG. 7.

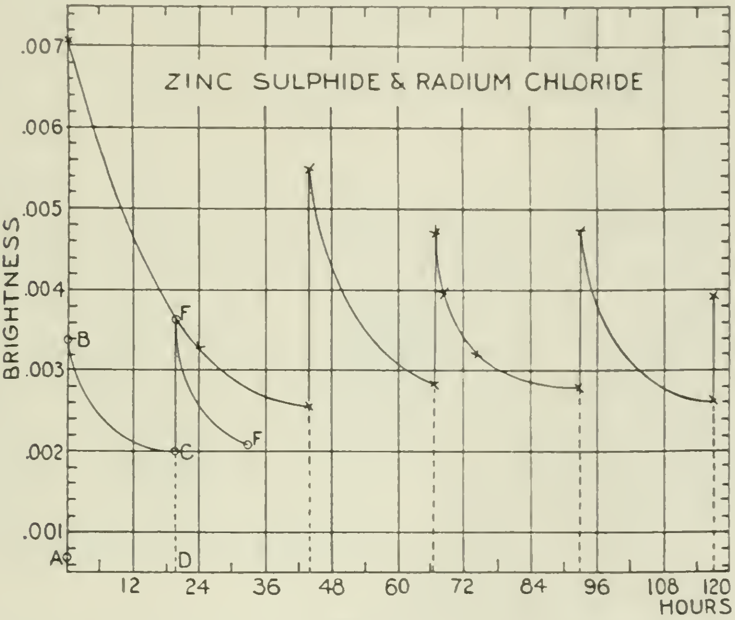


ing in this case was only to 221° C., while the previous heatings were to a temperature of a dull red heat. The marked effect of temperature is shown here. Divide ordinates by 2 for millilamberts.

In the curves of Figs. 4 and 5 there are indications that the intensity of the luminescence immediately after heating is increasing, due to the growth of the radio-active products from the radium.

In general, the rate of decay increases on this account also. There are some discrepancies, however, which are probably due to lack of temperature control; for where the temperature is low the slope of the curve is too gradual. This is shown in Fig. 4 by the second maximum of the curve connecting dots, where the curvature is more nearly that of a later portion of the curve after the third maximum.

FIG. 8.



In Fig. 6 are drawn some observations made with a tube containing radium chloride and barium chloride. The phenomenon here is exactly as described in connection with the previous figures.

The observations were begun about one week after the tube had been sealed. The observations marked with crosses were begun on July 31, 2.30 P.M.; those marked with circles were begun on August 21, 2.30 P.M.

The glass screen (screen No. 1) used to give an approximate color match in the photometric field was a high transmission green of the Corning Glass Company. Divide ordinates by 50 to have millilamberts approximately.

In Fig. 7 the behavior of a second sample of radium chloride is depicted. This was contained in a small quartz tube. The observations marked with crosses were begun August 3, 1.14 P.M., while those marked with circles were begun August 21, 1.59 P.M. The brightness is in millilamberts approximately. The gradual increase in the maximum here is very marked. The last maximum is probably due to heating to a higher temperature.

In Fig. 8 is shown the behavior of a tube containing radium chloride with which has been mixed zinc sulphide. The brightness here is approximately in millilamberts. The crosses mark observations begun July 24 and ended September 4; after an interruption observations were begun again on August 21 and marked with circles.

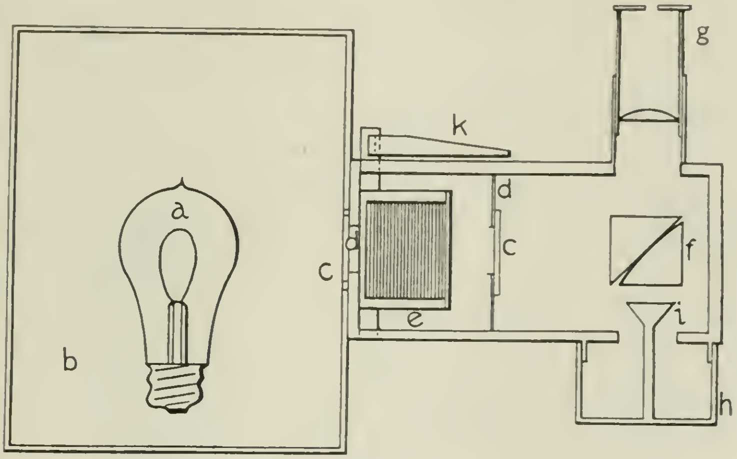
The peaks represent, as in the previous tubes, the brightness after the tube had been heated to dull red temperature and allowed to cool to room temperature. The maximum brightness given after heating is steadily decreasing. This is probably not what was to be expected from the properties of luminescent zinc sulphide. In a preparation containing only zinc sulphide and some other radium salt, such as is used in the ordinary commercial radium paints, the effect of heating is to decrease the brightness appreciably and permanently. We have made observations only upon one specimen, and have not been able to continue our observations upon this specimen.

The observations upon the effect of heating on zinc sulphide when stimulated by α-rays were not made with the photometric set-up, so that we can only say that heating to dull red heat or more does decrease the brightness. It may be that the gradual decrease in the maxima of the curve after successive heating is due to the added time interval of heating. The tube was small and the length of time during which it was in contact with the dull red plate was short. The decrease is dependent upon the aggregate time of heating.

It is proper here to remark that one purpose of this investigation was to see whether the self-luminous materials could not be utilized as a standard light-source in pyrometry and illuminometry, thereby making the pyrometer and illuminometer much more portable, for the standard lamp, together with the necessary batteries and electrical measuring instruments, constitutes the bulk of these instruments. Accordingly, samples of various grades of commercial radium paint were obtained from the following manufacturers: Denver Cold Light Company, the Standard Chemical Company, Radium Luminous Materials Corporation, and Cummings Chemical Company.

The following compact photometer (Fig. 9) was made use of in comparing these samples: The standard lamp *a* is a tungsten filament lamp mounted in a tin box *b*. On one side of the box is constructed a chamber for a neutral-tint absorbing screen *e*, for diffusing screens *c* and diaphragms *d*; together with a pair of

FIG. 9.



Compact photometer.

Lumner Brodhun prisms *f*, a support for the luminous material *i*, and an observing telescope *g*. The luminous material may be readily inserted by removing cap *h*.

The intensity of the light from the standard lamp was varied by means of the screen *e*. The use of the screen *e* eliminated the necessity for a long photometer bar, which was not available for this work at that time. This screen has been recently described by one of us.[2]

The zinc sulphide preparations on the market did not present such prospects of fulfilling our demands as did other radio-active luminous compounds, nor did they offer such interesting data as regards the mechanism of the light-production by radio-active materials. For these reasons observations on them were discontinued.

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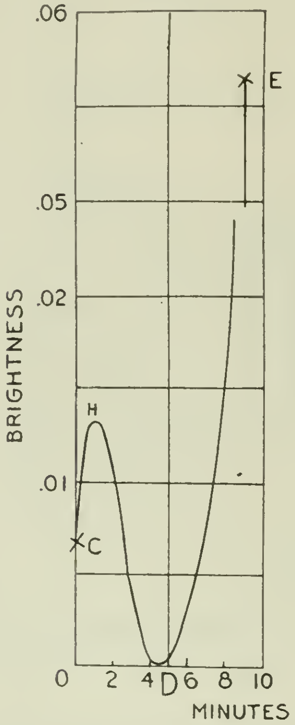
[2] JOURNAL OF THE FRANKLIN INSTITUTE, vol. 185, p. 539, April, 1918.

For the small amounts of the materials in small, narrow tubes the photometric field in this set-up was not suitable.

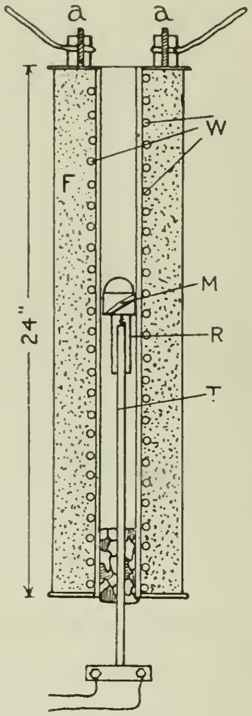
In most of the curves the points of minimum brightness have been connected by dotted lines to the time axis. At these points the material was heated. During the heating there is a very bright momentary flash, as noted above. After this flashing the material gradually becomes less luminous until it is no longer distinguishable from the dull red plate, and its own light is almost, if not entirely, extinguished. The time required for this to take place depends upon the rate of heating, but at most is only a few minutes, so that it cannot be shown with any clearness upon the charts.

FIG. 10.



Flashing effect of heating. Brightness *vs.* time.

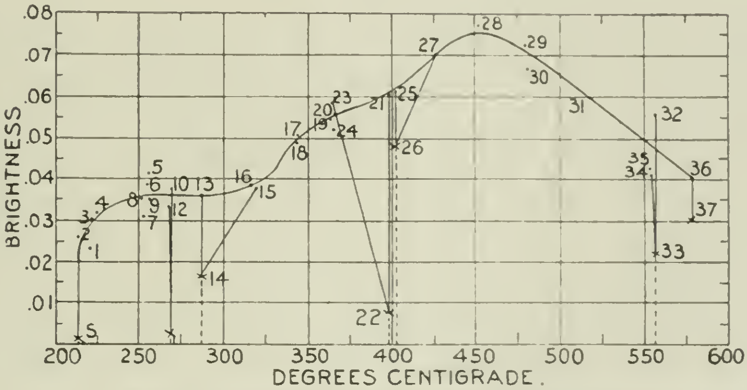
FIG. 11.



Furnace.

In Fig. 10, however, is an exaggerated view of this portion of the curve to show what takes place. For the sake of definiteness the lettering in Fig. 10 refers to corresponding points in Figs. 5 and 8. If we consider a specimen of luminous material which has been freshly prepared or has been kept for some time at ordinary temperatures, its brightness may be represented by some point *A*. After heating and allowing to come to room temperature its brightness is represented by *B*. The brightness steadily decreases, and after an interval of time, represented along the axis of abscissæ, will have decreased to a value represented by *C*. At this point the material is heated, and we refer to Fig. 10 to see its behavior. A sudden rise in brightness occurs (*CH*), so that temporarily the material may have a brightness comparable with its brightness at any other moment of its history. This brightness rapidly decreases to a minimum value approaching zero, *D*. Now when the material is again allowed to assume room temperature its brightness increases according to the curve *DE*. After some interval of time the brightness will again have fallen to a value *F* and the same operations repeated.

FIG. 12.



Effect of heating. Brightness *vs.* temperature.

The curve *CHDE* of Fig. 10 is only qualitative. It is very difficult to obtain absolute values during this short interval of time of the rapidly varying luminescence.

Having seen the importance of temperature upon the luminescence in these preliminary experiments, we conducted experiments for the purpose of gaining more accurate knowledge of this relationship.

An electric furnace *F* was equipped with a base metal thermocouple *T*, accurately calibrated, as shown in Fig. 11.

The radio-active material was placed in a small iron receptacle *R*, which was adapted to fit snugly over the end of the thermocouple and did not touch the walls of the furnace. The receptacle *R* was removed from the furnace by means of an iron hooked rod. The tube containing the luminescent material was removed from the receptacle by means of tweezers and laid upon an asbestos pad, where it was allowed to cool to room temperature.

The sample of material used for these observations was radium bromide No. 1, whose decay characteristics have been described in Fig. 5 above.

Referring to Fig. 12, where these observations are shown in a curve, *s* is the brightness of the material after having been kept at room temperature for several days after the last observation shown in Fig. 5 was made. After heating this tube to 220° C. in the furnace, its brightness was increased to a value represented by point 1. Other points near this temperature we obtained and plotted as 2, 3, and 4. Every point marked in consecutive order represents a determination of the brightness of this tube (in millilamberts) after having been heated in the furnace to a temperature corresponding to the abscissa of the point, and allowed to cool to room temperature.

We have found by trial that 10 to 15 minutes was ample time for the material to come to equilibrium in the furnace, so that the time between determinations of the brightness was of the order of 20 to 30 minutes, except in case of observations marked by crosses (11, 14, 22, 26, 33, 37), where hours had elapsed since the last heating.

For example, after the observation 10 was made the material was allowed to stand over night, during which time its brightness fell to 11. Upon heating the tube to a temperature corresponding very closely to 10, the brightness rose to 12. Between observations 13 and 14 several hours in the midday elapsed, while the brightness rose to 15 and 16 subsequent to heating to a temperature of 320° C. Between observations 21 and 22 is the interval of one night; after heating to a temperature corresponding to observations 19 and 20, points 23 and 24 are obtained; while when heated to a temperature corresponding to point 21, which is the last observation made on the previous day point, 25 is obtained. The sequence of observations at higher temperatures is given by the remaining numbered points.

The tube shows a maximum brightness when heated under these conditions to about 450° C. There is suggested here a means of estimating the temperature of small, inaccessible spaces.

The light given out by these luminescent materials stimulated by α-rays differs very markedly. The zinc sulphide preparations have a yellowish-green hue; willemite gives a very bright green hue; calcium tungstate has a bluish-green tint; cadmium phosphate a decided red color. Calcium sulphide is very similar to willemite; its phosphorescence, however, is very persistent; calcium salicylate is similar to calcium tungstate. Scintillations may be seen in all of these, and are particularly distinct in zinc and calcium sulphides and in willemite. When the substance is held close to the eye the scintillations may be seen without a lens.

We have prepared tubes containing radium chloride, bromide, and iodide. The luminescence of the iodide is very noticeably orange, while that of the chloride is more greenish-blue than the bromide. There seems here a distinct relationship between the atomic weight and the quality of luminescence produced.

Even in the same sample the color will vary with the age of the material. The brightest of our samples of radium bromide appear very white, but become decided blue and bluish-green as they decay. The preparations containing larger percentages of radio-active material appear more blue than those with smaller percentages. In all these cases, however, the Purkinje phenomenon is probably a most important factor. When the materials are observed in a tube the discoloration of the walls of the tube plays an important rôle. In a work [3] recently published the effects of discoloration were corrected for by separate determinations. In the observations recorded below the effects of such discoloration were eliminated entirely by another method. However, in all the observations recorded in our preliminary experiments the discoloration of the glass tubes was not corrected for nor eliminated. The phenomenon of discoloration of the glass tubes is probably a close kin to that going on in the luminous material itself. This semblance is strikingly seen in the case of radium bromide, which becomes very much discolored while decaying. There is another instance of this discoloration in the paleochroic halos. In the latter case it has been found by Jolly that the hypothesis of ionization is very tenable—the state of ionization persisting for ages in the highly insulating mica. This suggests ionization at the base of the two former cases. In all these cases discoloration disappears upon heating—

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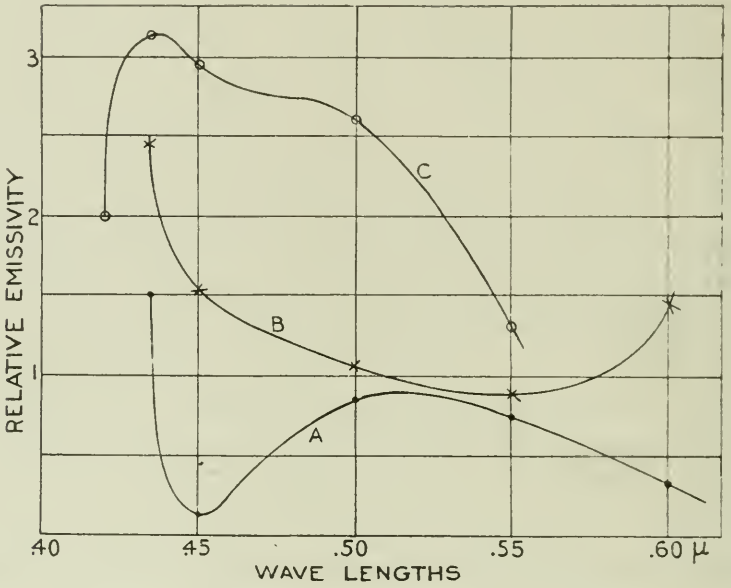
[3] Paterson, Walsh, and Higgins: *Proc. Phys. Soc. of L.*, June 15, 1917, p. 215.

in the first two accompanied with a flash of light. It is probable, also, that the paleochroic halos too would give out in the form of visible radiation some of the energy stored in them ages ago, that could be seen if a sufficient number of the halos were heated in a dark room. The discoloration in glass tubes varies with the kind of glass. Some become dark brown, others purple, others dirty gray.

We have recorded some spectro-photometric data relating to the tube containing the radium bromide No. 1 in Fig. 13. The data were obtained by means of a spectropyrometer. The tube was cemented across the slit. The ordinary calibration of the

FIG. 13.



Energy distribution. Emissivity *vs.* wave-length.

instrument cannot be used, and the ordinates are to be considered relative values only.

Curve *A* shows the distribution of the visible energy after the tube had been heated for one minute on the previous day; curve *B* gives the same immediately after having been heated, taken the same day as curve *A*; curve *C* shows the same after two weeks had elapsed, and then immediately after heating for two minutes on a dull red plate. It is undoubtedly the discoloration of the tube that is complicating matters here. These observations were made before we had made our final set-up for a series of tubes of known content described later, and should be repeated and extended.

The data which we are to discuss below refer to a series of samples of radium bromide—barium bromide as carefully prepared as possible. These samples were placed in small tubes and labelled Nos. 1, 2, 3, 4, and 5, in the order of their radium content—48.5, 31.2, 11.2, 3.0, and 0.51 per cent. radium element respectively. The tubes into which these materials were placed were made of "pyrex" glass; were somewhat less than two millimetres inside diameter, thin walled, and from four to five centimetres long. The tubes were made long to eliminate the effects of discoloration of the glass. When observations were made the material was shaken into one end of the tube, and shaken into the opposite end after every observation. The end at which the materials were observed discolored less than if the materials had been allowed to remain there constantly. Furthermore, this end could be slightly heated to clear the glass whenever desired without affecting the material.

This method was very satisfactory in all cases where the material was homogeneous in structure. In the case of the tube No. 3 of the last series, the shaking from end to end caused irregularities in the brightness to appear, because there was present a small core of the material, formed by fusion possibly, comparable in diameter with the diameter of the tube.

The photometric set-up for these observations is that in Fig. 1. A tungsten point-source lamp (110-volt, 100-watt) which had been calibrated for all voltages within the necessary range, is the standard. The range of brightness in this series of tubes was extensive, necessitating using different lamps or the lamps at different voltages or a series of screens. In our procedure we combined the last two methods on a photometer bar, three metres long.

There was usually present a color difference, to eliminate which would have called for a series of color screens or a variable-tint-screen. We used one and the same screen to give an approximate color-match for all samples for all times. This consisted of a disc of "daylight" glass for tungsten lamps, together with another plate of cobalt glass. The first was about 5 mm. thick and the second 3 mm. thick. These pieces were cemented together. This we called screen No. 2. The screen used to reduce the intensity when the range of the bar had been reached was a ground-glass screen labelled No. 4. The transmission of screen No. 4 was obtained at several intensities of illumination and with the lamp at several different voltages. The variations were not large and well within our experimental errors. The transmission is 13 per cent. To obtain the last observations recorded in Fig. 15 a second ground-glass screen was used, whose transmission is 21.6 per cent.

The transmission of screen No. 2 was more difficult to obtain. It varied with the voltage of the lamp and with the intensity of illumination for every voltage. The difficulties of comparing the intensities of colored light at relatively low intensities are well known, but no satisfactory method has been found to eliminate them. The Purkinje phenomenon is very strong, and in extreme cases the inverse square law cannot be relied upon for calculating the intensity. We have determined the transmission of screen No. 2 by two methods: first, by making a photometric balance with and without the screen, with all conditions precisely the same as when observations were made for record of the luminous materials when the screen was used; secondly, by the use of an illuminometer, when the relative position of the screen remained the same, but the method of observation was altered. The two series of values differed less from each other than the separate values obtained by either method when the intensity was varied. The intensity to which the transmission is referable is 71 millilamberts. This is an intensity which we could get upon the bar with the lamp at any voltage within the range used. With the lamp voltage at 80, 85, 90, and 95 the transmission is 0.064; with the lamp voltage at 100, 110, 115, and 120 the transmission is 0.071. These values were assumed constant for all intensities.

The reflection factor of the celluloid disc coated with magnesium oxide was determined by means of an illuminometer, as previously described, and is 70.9 per cent.

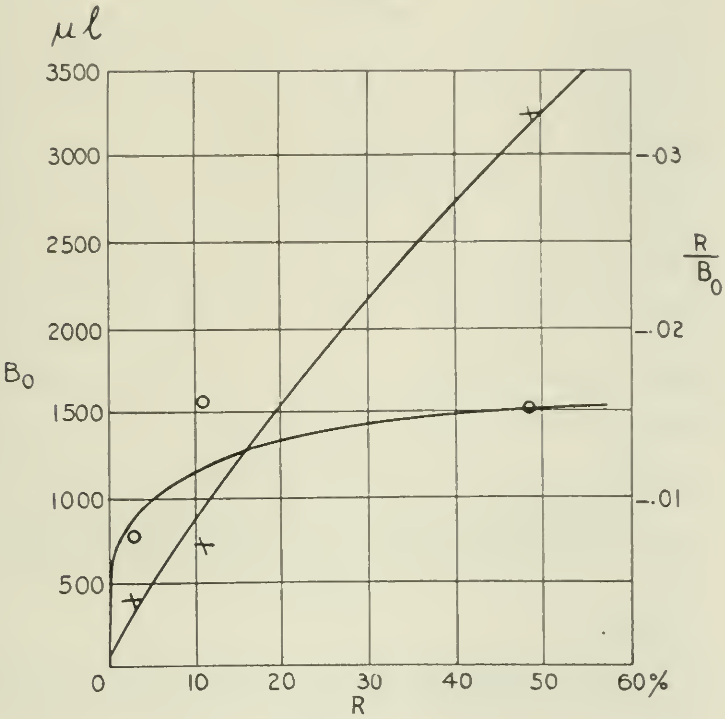
The series of tubes were prepared on October 23 from the same solution concentrated by successive crystallizations; were then dried and placed in small sealed tubes, where they were kept for a few days before their γ-ray activity was measured and the percentage of radium element calculated. The material was then placed in the small tubes for observation.

By means of the furnace shown in Fig. 11 we found that it was necessary to heat these preparations to a temperature of 480° C. to get maximum brightness.

On October 24, 3.20 P.M., all five samples were exposed to the atmosphere by breaking the ends off the tubes and inserted into the furnace. For a receptacle in this case a large brass cylinder was used, having small holes for receiving the tubes and having a larger hole in the opposite end to receive the thermocouple. By this means we were assured that all the tubes would be subjected to the same temperature, which was 520° C.

Observations were made of the brightness of each tube, and are as follows: No. 1, 3012 μl; No. 2, 610.1; No. 3, 469; No. 4, 283; No. 5, 130. Our observations were interrupted until November 19, 4.21 P.M. Then we transferred all the samples into new tubes, except No. 1, and obtained a new sample of No. 2 from the original stock. The transfer was made on account of the fact that the size and shape of the tubes were not satisfactory. No. 2 now had become almost non-luminous. We had reason to suspect No. 2 had become contaminated in manipulating it. After heating in the furnace to a temperature of 480° C., the brightness of tubes 1, 3, 4, and 5 was 3100, 764, 590, and 146 respectively.

FIG. 14.

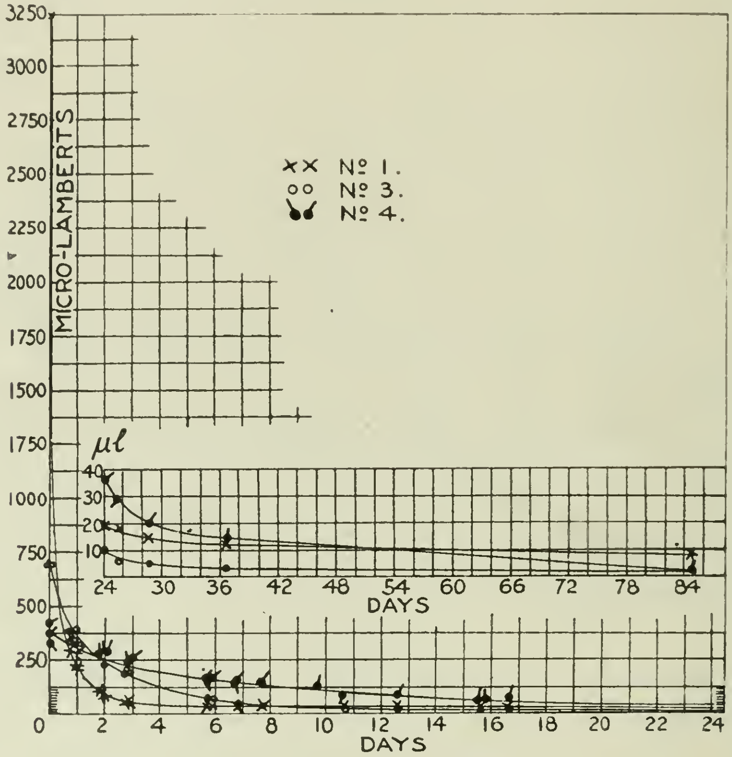


Effect of varying percentages of radium on initial brightness.

On November 20, 2.33 P.M., tubes Nos. 1, 3, and 4 were opened, placed in the furnace, and heated to 520° C. From this time on we made continuous observations on these three tubes, as shown in Fig. 15. No. 5 was accidentally contaminated with oxide from the furnace.

One of the striking features about these curves is that they cross and recross. This is in contrast to similar curves recorded for the zinc sulphide paints. Another feature is the fact that the relationship between initial brightness and percentage of radium element is not linear, but reaches a saturation value. This is shown in Fig. 14. The type of curve which seems, from our data, to be required, is given by $B_o = AR^c$. Where B_o = initial brightness; R = per cent. radium; A and c are constants; $A = 141.8$, $c = 0.8$.

FIG. 15.



Final data. Brightness *vs.* time.

The curve for No. 4 is less definite than those for Nos. 1 and 3. This scattering of the observations is due to the rather compact core, which presented a different aspect whenever the tube was shaken. Curve for No. 1 falls below both the lower curves within the first 24 hours, and the curve for No. 3 falls below that for No. 4 within 48 hours. After 9.5 days, however, the curve for No. 3 has fallen below that for No. 1 and continues so; while the curve for No. 4 falls below that for No. 1 for 10 weeks, and will eventually also fall below the curve for No. 3. Thus, after an interval of several months, the brightness of these materials will again arrange themselves in the order of the radium content.

Although the crossing of the curves is in general agreement with Rutherford's theory, nevertheless a simple exponential curve is not adequate, through the extent of time shown, to represent the data. On the other hand, the equations of Walsh[4] become very cumbersome to test accurately with the data here. It appears, however, that they cannot be satisfactory on account of the intersections.

There is always some uncertainty in our tubes as to the exact concentration of the α-rays whenever they are heated.

In the theory of the radio-active paints it is always assumed that the α-rays only need be taken into account; whereas the effects of the γ-rays may become noticeable at low intensity when the material is almost exhausted. The stimulation by γ-rays is less drastic and more similar to the stimulation to produce ordinary fluorescent effects, and where, if there is decay, it is considerably less rapid.

The factors involved in the production of light by these materials that must be considered by any theory regarding it are as follows:

1. A destruction.
2. A change in optical properties.
3. A reconstruction.

The fundamental fact that the brightness decays more rapidly than the decay of the radio-active material is evidence of some sort of destruction. During this period of decay the color of the material changes. It becomes optically more opaque to the visible radiation, just as a photographic plate will darken when exposed to α-rays, β-rays, or γ-rays. This darkening is sometimes very marked. Due to this opacity, the visible radiation produced below the surface of the material is more and more absorbed as time goes on, and therefore can add less and less to the surface brightness. Changes in color have been observed in barium platinocyanide when stimulated by rays from radium. To take proper reckoning of this element a knowledge of the laws of blackening by radio-active radiations—*e.g.*, of glass, mica, or photographic plates—is essential.

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[4] *Proc. R. S.*, 93A, October, 1917, p. 550.

Some form of reconstruction seems necessary to account for the ever-decreasing rate of decay as the material becomes older. This reconstruction may be one of several kinds. It may be a re-forming of the "active centres" postulated by Rutherford and which is taken account of as a recombination factor in recent work;[5] or it may be that of the more simple and definite concept of recombination of ions; or it may be of the same nature as the reconstruction going on in the ordinary fluorescent materials excited by radiation of some definite wave-lengths, where there is no disruption of molecules or groups of molecules, or where there may not even be any formation or recombination of ions; in case of the luminous materials under consideration it would have to be assumed that the stimulus is the γ-rays or other secondary radiations.

The data presented in Fig. 12 clearly show that for any temperature there is a definite equilibrium state; so that, if a certain configuration of molecules is essential in order to produce light with α-rays, these results would indicate that there is some constant which would be indicative of the number of such configurations at any temperature, and that the assumption would be logically made that these configurations are breaking up and reforming at ordinary temperatures. It should be pointed out that this same condition of affairs would be consistent with an ionization hypothesis. A study of the electrical resistance of the substance before and after heating and while decaying may throw light upon this point.

The curve of Fig. 12 shows unmistakably that the luminescence is an accompaniment of a molecular state brought about by heating, whatever be the immediate mechanism of the light-production. The humps in this curve indicate, also, that there are several phases of the substance.

It is obvious that if the initial brightness or any given percentage of the initial brightness that is possible with any one sample of material could be readily reproduced the luminescent material is theoretically adaptable to be used as a standard light-source in photometry and pyrometry and in other instances where portability and compactness are most desirable. It is more radical to suggest, in the present state of knowledge, that in these self-luminous compounds there may be an absolute standard of brightness for illuminating engineering! In the cases which we have observed there is reason to believe that the luminous material may have a life equal to the life of the radio-active substance used. In the case of radium the half-life is 1730 years. The nature of the decay in radium is very well known, so that the decrease in brightness due to the decay of the stimulus could be calculated for any time during this period.

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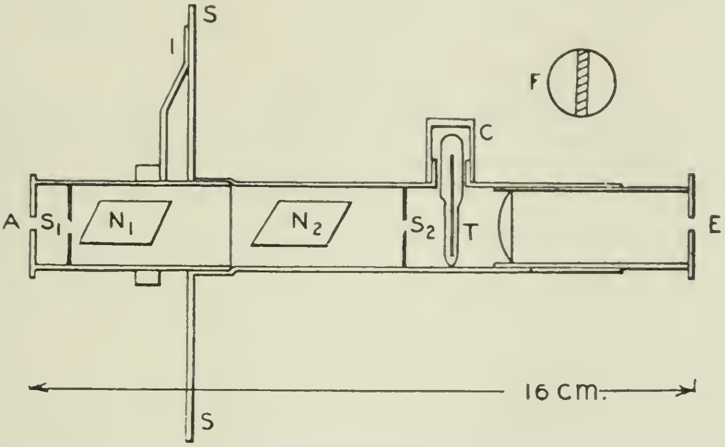
[5] Walsh, *loc. cit.*

We have constructed such instruments, using these materials along the lines shown in Figs. 16 and 17. In both of these designs we have used Nicol prisms merely as a convenient method to vary the intensity of the light.

FIG. 16.



Optical instrument.

The symbols refer to both figures: N_1, N_2, Nicol prisms; S_1, S_2, diaphragms; I, index; S, graduated disc; T, tube containing luminous material; c, covering to exclude extraneous light; A, aperture through which the rays of light from the surface looked at enter; E, eye-piece; F, photometric field (shaded portion is illuminated by the tube T).

In Fig. 16 the tube T containing the luminous material is a hard-glass capillary tube whose opposite sides for a distance of about 1 cm. are ground plane and polished.

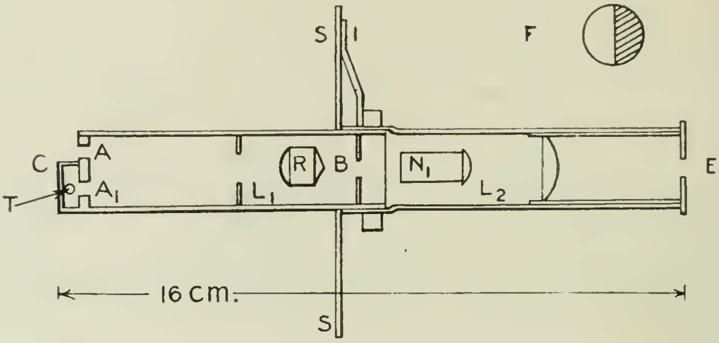
The tube is viewed directly and less radio-active material is required. The brightness of the tube *T* must be the brightness of the least bright surface that is to be looked at, or less.

In securing a photometric balance the light from the source looked at is reduced by rotating the Nicol prism N_1. The amount by which the intensity was reduced is read on the scale *S*.

The brightness of the tube *T* can at any time be brought back to its original value by removing and heating.

In Fig. 17 the light from the tube *T* undergoes the same losses as the light from the source. There is no limit to the brightness of the tube *T*, but it requires more radium to make it appear of any definite brightness in the field of view than in the previous set-up.

FIG 17.



Optical instrument.

The light collimated by the lens *L* passes through the Rochon prism *R,* where the two oppositely polarized pencils of light from *A* and A_1 are produced. These pencils are brought together by the bi-prism *B*; through the Nicol N_1 and lens L_2.

We hope, in a future communication, to present further data showing in more detail the behavior of these materials and bearing both upon the theory and the use of them.

We wish to express our thanks and appreciation to the parties mentioned in the text, both for materials and encouragement, and particularly to the Cummings Chemical Company, of Lansdowne, Pa., who furnished all of the various salts used in these experiments.

PHYSICS OF THE AIR.*

BY

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CHAPTER XIV (*Continued*).

Crushing Effects.—One of the more surprising phenomena of the lightning discharge is the crushing of hollow conductors, an effect that gives some idea of the strength of current and quantity of electricity involved, and therefore deserves a full discussion.

Pollock and Barraclough[117] have described and explained this phenomenon in connection with a hollow copper cylinder: outside diameter 18 mm., inside 16 mm., lap join 4 mm. wide, 2 mm. thick. In what follows, however, reference will be had to a remarkable and even more instructive product of the same phenomenon kindly lent by Mr. West Dodd, of Des Moines, Iowa. Fig. 114 shows two originally duplicate (so reported), hollow, copper lightning rods, one uninjured (never in use), the other crushed by a discharge. The uninjured rod consists of two parts, shown assembled in Fig. 114, and separate in Fig. 115. The conical cap, nickel plated to avoid corrosion, telescopes snugly over the top of the cylindrical section, and when in place, where it is left loose or unsoldered, becomes the ordinary discharge point.

The dimensions are:

Section	Outside Diameter	Inside Diameter
Cylinder	16.0 mm.	14.65 mm.
Cone shank	17.4 mm.	16.0 mm.

Length of conical cap, cylindrical portion, 7 cm., total 19 cm.

Both the cylindrical and the conical portions of the rod are securely brazed along square joints.

The general effects of the discharge, most of which are obvious from the illustrations, were:

1. One or two centimeters of the point were melted off.
2. The conical portion of the top piece and all the cylindrical

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[117] *Jr. and Proc. Roy. Soc. N. S. Wales,* 39, p. 131, 1905.

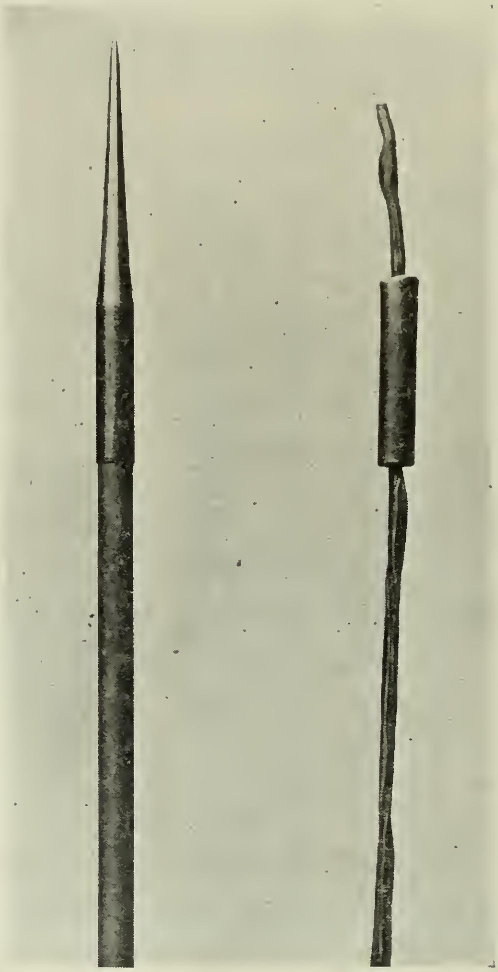
* Continued from page 232, vol. 186, August, 1918.

rod except the upper 2 centimeters, roughly, within the cap, were opened along the brazed joint.

3. The brazing solder appears to have been fused and nearly all volatilized—only patches of it remain here and there along the edges.

4. The upper end of the cylindrical rod was fused to the cap just below its conical portion.

FIG. 114.



Originally duplicate hollow copper lightning rods; one never used, the other crushed by a lightning discharge.

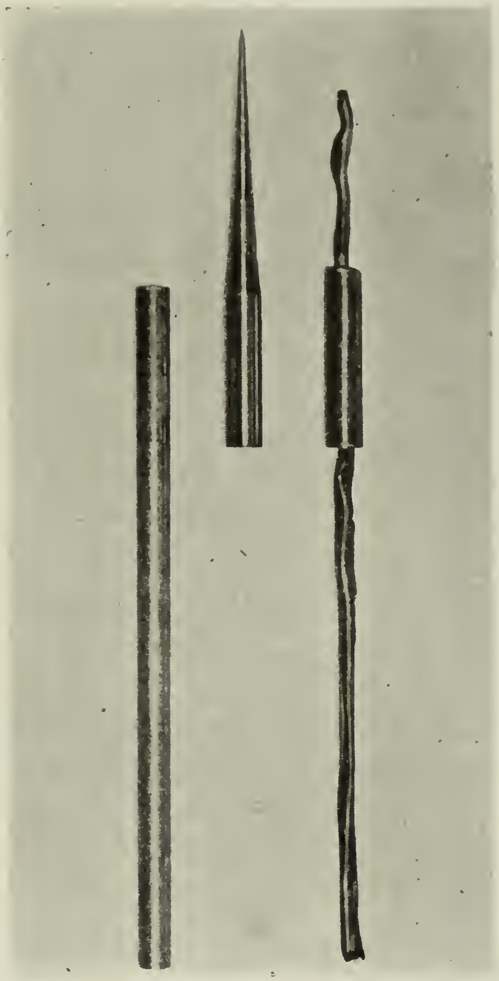
5. The rod was fused off where it passed through a staple. Whether a bend in the conductor occurred at the place of fusion is not stated.

6. The collapse of the cylindrical rod extended up about 5 centimeters into the cap.

7. The cylindrical portion of the cap, about 7 centimeters in length, was uninjured, even the brazing was left in place.

What force or forces caused this collapse? Possibly it might occur to many that it was produced by the reaction pressure from an explosion-like wave in the atmosphere due to sudden and intense heating. But however plausible this assumption may seem at first there, nevertheless, are serious objections to it, some of which are:

FIG. 115.



Same as Fig. 114, except unused rod is not assembled.

(*a*) While explosions with their consequent pressures may be obtained by passing a powerful current along a conductor they seem to occur only with the sudden volatilization of the conductor itself, which in this case did not take place.

(*b*) The heating of the enclosed air should have produced a pressure from within more or less nearly equal to the pressure simultaneously caused from without, and thereby have either prevented or at least greatly reduced the collapse.

(*c*) The assumption that the crushing of the conductor was due to mass inertia of the suddenly heated air offers no solution whatever of the collapse of the rod up into the shank of the cap.

For these reasons it seems that the idea that the collapse of the conductor may have been caused by the reaction pressure of an explosion wave in the atmosphere due to sudden heating, is untenable.

Probably the correct explanation of the collapse, as already offered by Pollock and Barraclough,[118] an explanation that at least must involve an important factor, is as follows:

Each longitudinal fiber, as it were, of the conductor attracted every other such fiber through the interaction of the magnetic fields due to their respective currents, and the resulting magnetic squeeze on the hollow rod, whose walls were weakened by the heating of the current, caused it to collapse in the manner shown.

As is well known the force, f, in dynes per centimeter length, with which a straight wire carrying a current of I amperes is urged at right angles to the direction of the lines of force of a uniform magnetic field of intensity H is given by the equation

$$f = \frac{IH}{10}$$

Also, the value of H, r centimeters from a relatively very long straight conductor carrying I amperes, is given by the relation

$$H = \frac{2I}{10r}$$

Now, as developed by Northrup[119] in the theory of his heavy-current ammeters, let a, Fig. 116, be the outer, and b the inner radius of a tubular conductor, and let r be the radius of any intermediate tube of infinitesimal thickness, dr. Also let the conductor as a whole carry a uniformly distributed current of I amperes. Then the value of the magnetic force, at the end of the radius r, is given by the equation

$$H_r = \frac{2\,I\,(r^2-b^2)}{10\,r\,(a^2-b^2)}$$

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[118] *Loc. cit.*

[119] *Trans. Amer. Electrochem. Soc.* 15, p. 303, 1909.

which depends upon the fact that only those portions of the current less than r distant from the axis are effective—the forces due to the outer portions neutralizing each other. Also the strength of the current, dI, carried by the cylinder of radius r and infinitesimal thickness, dr, is given by the relation

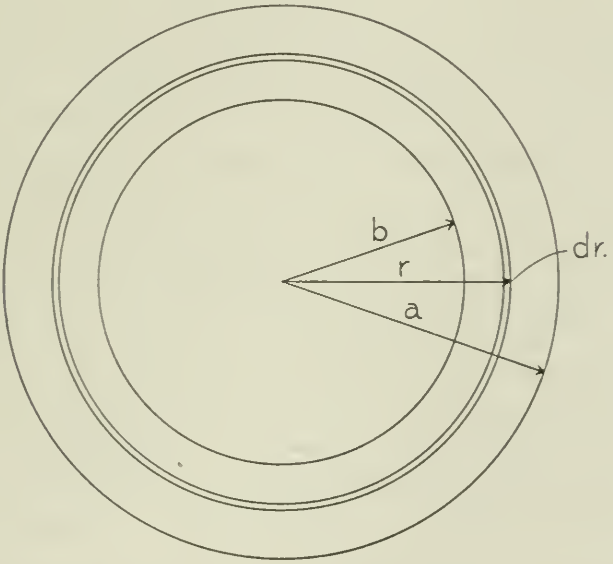
$$d\,I = \frac{2\,I\,r\,dr}{(a^2-b^2)}$$

Hence, under the assumed conditions, the normal pressure, dP, per unit area on the cylinder of radius r and thickness, dr, may be determined by the equation

$$dP = \frac{2\,I\,r\,dr}{2\,\pi\,r\,10\,(a^2-b^2)} \times \frac{2\,I\,(r^2-b^2)}{10\,r\,(a^2-b^2)}$$

Hence the total normal pressure, P, per square centimeter of the *inner* surface is given by integrating the above expression between the limits b and a. That is,

FIG. 116.



Section of a hollow tubular conductor, inner radius, a, outer radius, b.

$$P = \frac{2\,I^2}{100\,\pi\,(a^2-b^2)^2}\left(\int_b^a r\,dr - b^2\int_b^a \frac{dr}{r}\right)$$

$$= \frac{2\,I^2}{100\,\pi\,(a^2-b^2)^2}\left[\tfrac{1}{2}\,(a^2-b^2) + b^2\log_e\frac{b}{a}\right]$$

$$= \frac{I^2}{100\,\pi\,(a^2-b^2)}\left(1+\frac{2\,b^2}{a^2-b^2}\log_e\frac{b}{a}\right)$$

Substituting for a and b their numerical values, 0.8 cm. and 0.7325 cm. respectively, it is found that

$$P = \frac{I^2}{379.1}$$

If we assume P, the pressure in dynes per square centimeter of the inner surface, to be 10^6, approximately one atmosphere, then

$$I = 19{,}470 \text{ amperes, approximately.}$$

If the lightning discharge were alternating the current density would be greatest in the outer portions of the conductor, and therefore the total current would have to be still heavier than the above computed value to produce the assumed pressure. However, from reasons already given, it seems extremely probable that the discharge is unidirectional and not alternating, and therefore that the computed strength of current, though of minimum value, is substantially correct.

Quantity of Electricity in Discharge.—To determine the amount of electricity involved in a lightning discharge it is necessary to know both its duration and the average strength of current. Both factors and, therefore, the total charge are known to vary greatly, though actual measurements have been comparatively few and even these as a rule only crudely approximate.

It has often been stated that the duration of a single discharge, or single component of a multiple discharge, is not more than one one-millionth of a second. Some have computed a duration of roughly one one-hundred thousandth of a second, while others have estimated that it can not be greater than one forty thousandth or, at most, one thirty-five thousandth of a second. Possibly many discharges are as brief as some of these estimates would indicate, but there is ample reason to believe that others are much longer. Thus one occasionally sees a streak of lightning that lasts fully half a second without apparent flicker, while more or less continuous or ribbon discharges are often photographed by moving cameras. But in addition to these evidences we have also a number of time-measurements made by Rood[120] with a rotating disk, ranging from less than 1/1600 second up to 1/20 second, and others, 38 in all, by DeBlois[121] with an oscillograph, ranging from 0.0002 second to 0.0016 second. In one case De Blois found the durations of 5 sequent discharges to be 0.0005, 0.0015, 0.0016, 0.0014 and 0.0012 second respectively, or 0.0062 second as the summation time of these principal components of the total discharge. Hence it seems probable that the actual time of a complete discharge, that is, the sum of the times of the several components, may occasionally amount to at least 0.01 second.

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[120] *Amer. Jr. Sci.*, vol. 5, p. 163, 1873.

[121] *Proceedings Am. Inst. Elec. Eng.*, vol. 33, p. 568, 1914.

The second factor mentioned above, the strength of discharge, is even more difficult to determine, and but few estimates of it have been made.

Pockels,[122] adopting the ingenious method of measuring the residual magnetism in basalt near a place struck by lightning and comparing these quantities with those similarly obtained in the laboratory, concluded that the maximum strength of current in such discharges amounted occasionally to at least 10,000 amperes. However, the loss of magnetism before the measurements were made, and other unavoidable sources of error, indicate that the actual current strength probably was much greater than the estimated value—that the maximum strength of a heavy lightning discharge certainly amounts to many thousands of amperes, occasionally perhaps to even one hundred thousand.

Since the above estimates are very rough it would be well to check them, even though the check itself be equally crude. Hence it may be worth while further to consider the crushed lightning rod with this particular object in view.

From the dimensions already given of this rod, outside diameter 1.6 centimeters, inside diameter 1.465 centimeters, it follows that its cross sectional area is about .325 square centimeter, and its weight, therefore, approximately 2.9 grams per centimeter length. Further, from the fact that the brazed joint was opened and most of the solder removed, apparently volatilized, and the further fact that the rod itself, in several places, indicates incipient fusion, it would seem that the final temperature may have been roughly 1050° C. If so the rod must have been heated about 1025° C., since its temperature just before being struck probably was approximately 25° C. But the average specific heat of copper over this temperature range is roughly 0.11 and therefore the calories generated per centimeter length about 327.

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[122] *Annalen d. Phys.*, **63**, p. 195, 1897; **65**, p. 458, 1898; *Met. Zeit.*, **15**, p. 41, 1898; *Phys. Zeit.*, **2**, p. 306, 1901.

Now one ampere against one ohm generates 0.24 calories per second. Hence, since the resistance of the uninjured or check rod, as kindly measured by the Bureau of Standards, is practically that of pure copper, the average resistance of the crushed conductor over the assumed temperature range probably was about 17 microhms per centimeter length,[123] we have the equation

$$\frac{24}{10^2} I^2 \frac{17}{10^6} t = 327,$$

in which I is the average strength of current, and t the actual time of discharge. Assuming that $t = .01$ sec. we get, roughly,

$$I = 90{,}000 \text{ amperes.}$$

A current of this average value would indicate a maximum value of perhaps 100,000 amperes.

It was computed above that a current of 19,470 amperes in the given hollow conductor would produce on it a radial pressure of 10^6 dynes per square centimeter, or about one atmosphere. Hence 100,000 amperes would give a pressure of 2638×10^4 dynes per square centimeter, or approximately 400 pounds per square inch; enough, presumably, to produce the crushing that actually occurred.

A current of 90,000 amperes for .01 second would mean 900 coulombs or 27×10^{11} electrostatic units of electricity; certainly an enormous charge in comparison with laboratory quantities, but after all a surprisingly small amount of electricity, since it would electrolyze only .084 of a gram of water. It must be distinctly remembered, however, that these estimates are exceedingly rough, and further that this particular discharge presumably was exceptionally heavy since it produced an exceptional effect.

An interesting method of measuring the resultant electric exchange between earth and cloud incident to a lightning discharge recently has been used by C. T. R. Wilson.[124] Values up to about 50 coulombs were found, but it is not stated whether the discharges were single or mutliple, nor are their durations given.

From the above various observations and experiments, therefore, it appears that in some cases the strength of current in a lightning discharge probably amounts to many thousands of amperes, and that the total duration of the individual or partial discharges may be several thousandths of a second.

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[123] Northrup, JOURNAL FRANKLIN INSTITUTE, 1914, 177, p. 15.

[124] *Proc. Roy. Soc. A.*, **92**, p. 555, 1916.

Danger.—It is impossible to say much of value about danger from lightning. Generally, it is safer to be indoors than out during a thunderstorm, and greatly so if the house has a well-grounded metallic roof or properly installed system of lightning rods. If outdoors it is far better to be in a valley than on the ridge of a hill, and it is always dangerous to take shelter under an isolated tree—the taller the tree, other things being equal, the greater the danger. An exceptionally tall tree is dangerous even in a forest. Some varieties of trees appear to be more frequently struck, in proportion to their numbers and exposure, than others, but no tree is immune. In general, however, the trees most likely to be struck are those that have either an extensive root system, like the locust, or deep tap roots, like the pine, and this for the very obvious reason that they are the best grounded and therefore offer, on the whole, the least electrical resistance.

If one has to be outdoors and exposed to a violent thunderstorm, it is advisable, so far as danger from the lightning is concerned, to get soaking wet, because wet clothes are much better conductors, and dry ones poorer, than the human body. In extreme cases it might even be advisable to lie flat on the wet ground. In case of severe shock, resuscitation should be attempted through persistent (hour or more, if necessary) artificial respiration and prevention from chill.

As just implied, the contour of the land is an important factor in determining the relative danger from lightning because, obviously, the chance of a discharge between cloud and earth, the only kind that is dangerous, varies somewhat inversely as the distance between them. Hence thunderstorms are more dangerous in mountainous regions, at least in the higher portions, than over a level country. For this same reason, also (inverse relation between distance from cloud to earth and frequency of discharge between them), there exists on high peaks a level or belt of maximum danger, the level, approximately, of the base of the average cumulus cloud. The tops of the highest peaks are seldom struck, simply because the storm generally forms and runs its course at a lower level.

Clearly, too, for any given section the lower the cloud the greater the danger. Hence a high degree of humidity is favorable to a dangerous storm, partly because the clouds will form at a low level and partly because the precipitation, and probably therefore the electricity generated will be abundant. Hence, too, a winter thunderstorm, because of its generally lower clouds, is likely to be more dangerous than an equally heavy summer one. Finally, as already explained, cyclonic or other cross-current thunderstorms presumably are more dangerous, than those due to local heating, and therefore the thunderstorm of middle latitudes generally more dangerous than one of equal severity in the tropics.

It may also be interesting to note that the front edge of a thunderstorm probably is more dangerous than any other portion; more dangerous because it is immediately beneath the region of most active electrical generation, and because objects here often still are dry and therefore if struck more likely to be penetrated and fired than later when wet and thus partially shielded by conducting surfaces.

Protection.—If, as seems quite certain, the lightning discharge follows, or tends closely to follow, the instantaneous lines of electric force then it is obvious that whatever changes the direction of this force must correspondingly alter the path the flash shall take. To the extent then that the direction of electric force near the surface of the earth can be changed, but in general to only this extent, lightning protection is possible. If also the strength of the field could materially be reduced clearly the discharges might be rendered less violent and even less frequent, but, as will be explained presently, there is no evidence that the strength of the field can greatly be altered by any practicable means. Hence it appears that protection from lightning must be sought through directional control, which is both possible and practical,[125] rather than through prevention.

Assume, in accordance with observation, that over an extended horizontal surface, a prairie for instance, the lines of electric force are vertical; determine how the field of force will be modified by the presence of a given structure. Obviously if the structure itself consists of such non-conducting materials as wood and stone there will be but little directional change of the electric force. If, however, it is made of a conducting substance the direction of the force will be changed, but to an extent and over an area that depend upon the size and shape of the structure in question. In general this effect is not calculable, but fortunately it may be definitely computed in the special case of a conducting semi-ellipsoid with vertical axis and standing, as would a right one, on the conducting surface—the actual surface if wet, somewhat below if dry. The ground and all parts of the conductor, unless actively discharging, will have the same potential. Hence by varying the values of the three diameters of the semi-eclipsoid a fair approximation may be made to many ordinary structures and their effects on the electric field estimated, in some cases roughly, in others with even a high degree of accuracy. Thus, by making each of the horizontal diameters small and the vertical one relatively very large, the modification of the field by a single upright metallic rod may be computed very closely, and its efficiency as a protection against lightning approximately determined. This has recently been done by Sir J. Larmor and Mr. J. S. B. Larmor,[126] who say that

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[125] O. S. Peters, "Protection of Life and Property Against Lightning." Technologic Paper, 56, Bureau of Standards, Washington, D. C., 1915. Also R. N. Covert, "Modern Methods of Protection Against Lightning," *Farmers' Bulletin 842*, Department of Agriculture, Washington, D. C., 1917.

"In fact, if the undisturbed vertical atmospheric field is F, the modified potential

$$V = -Fz + Az \int_{\epsilon}^{\infty} \frac{d\lambda}{(a^2+\lambda)^{1/2}(b^2+\lambda)^{1/2}(c^2+\lambda)^{3/2}}$$

will be null over the ground, and also null over the elllipsoid (a, b, c), provided

$$\frac{F}{A} = \int_{0}^{\infty} \frac{d\lambda}{(a^2+\lambda)^{1/2}(b^2+\lambda)^{1/2}(c^2+\lambda)^{3/2}}$$

"For our special case of a thin symmetrical semi-ellipsoid of height c, this gives

$$V = -Fz + Az \int_{\varepsilon}^{\infty} \frac{d\lambda}{\lambda(c^2+\lambda)^{3/2}}$$

"The value of this integral, however, increases indefinitely towards its lower limit as ϵ falls to zero, when a and b are null. Thus as the semi-ellipsoid becomes thinner the value of A diminishes without limit; that is, the modification of the field of force by a very thin rod is negligible along its sides unless close to it. A thin isolated rod thus draws the discharge hardly at all unless in the region around its summit."

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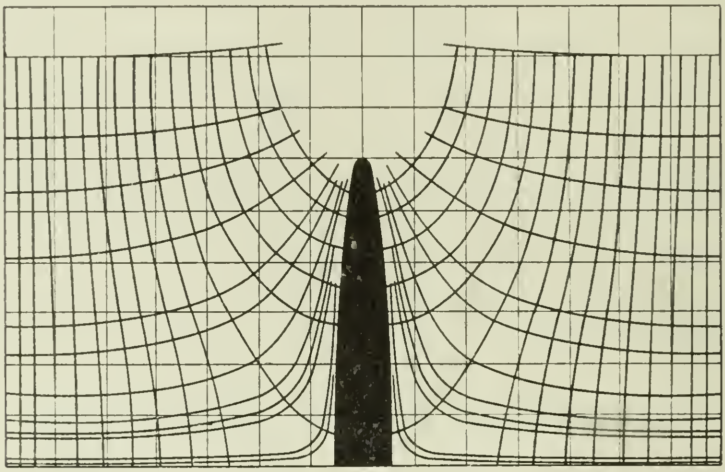
[126] *Proceedings Roy. Soc. London*, A 90, p. 314, 1914.

This is not to be taken as a condemnation of lightning rods in general. It only shows that a single vertical rod affords but little protection to things in its neighborhood. When, however, the horizontal diameters of the semi-ellipsoid are of appreciable length the directions of the otherwise vertical lines of force are greatly changed for some distance on all sides, as illustrated by Fig. 117, adapted from the paper quoted above. Hence one method, and so far as known the only method, of at least partially protecting an object from lightning consists in surrounding it by a hollow conductor, or by a well-grounded conducting cage. Perfect protection ordinarily is not practical, if even possible.

FIG. 117.



Vertical field of electric force disturbed by a conducting, semi-ellipsoidal column.

By this method the lightning that otherwise would hit at random is guided to the conducting system and through it, if all goes well, harmlessly to the ground. It must be clearly remembered, however, that this discharge, though in all probability unidirectional, is extremely abrupt and of great amperage and therefore possesses the dangerous voltage and inductive properties of alternating currents of high frequency and large volume. It should also be remembered that although the successive partial discharges that make up the usual lightning flash follow the same ionized path, this path itself, shifted by the winds, probably often guides one or more of the secondary or sequent discharges to an entirely different object from that hit by the first.

From these fundamental principles it is easy to formulate general rules (details may be varied indefinitely) for the construction of an efficient system of lightning protection.

CONDUCTORS.

Since lightning discharges occasionally involve very heavy currents, it is necessary that the conductors of the protective system be sufficiently large to prevent fusion. Probably copper is the best material to use, mainly because non-corrosive, or practically so, in the atmosphere and therefore very durable, though aluminum and galvanized iron are also good. If copper, a weight of 370 grams per meter (4 ounces per foot) might suffice, but a greater weight possibly would be better. The shape of the cross section appears to be of comparatively small importance.

TERMINALS.

Because of the distortion of the electric field due to the object to be protected, house for instance, and to the system of conductors, each ridge, peak, chimney and other highest point should be capped or surmounted by a conductor that is well grounded.

It would be better if the conductor extended 2 meters or so above each of these salients, though the protection is still fair to good with much shorter projections, or even none at all. Whether or not each projection in turn is provided with the customary sharp points probably is of small importance—rather a matter of taste or sentiment than a necessity. To be sure, it often is asserted that sharp points discharge so freely that they thereby largely *prevent* lightning. But this assumption has little support from observation or experiment. Lodge,[127] for instance, says: "*I find that points do not discharge much till they begin to fizz and audibly spit; and when the tension is high enough for this, blunt and rough terminals are nearly as efficient as the finest needle points.* The latter, indeed, begin to act at comparatively low potentials, but the amount of electricity they can get rid of at such potentials is surprisingly trivial, and of no moment whatever when dealing with a thundercloud."

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[127] "Lightning Conductors and Lightning Guards," London, 1892, p. 370.

SYSTEM.

Because a single rod modifies the electric field only in its near neighborhood, and because the wind shifts the ionized or conducting path during the interval between successive partial discharges, it is obvious that the smaller the spaces left bare by the conductive covering the more effective the protection. A steel frame building with the framing well grounded from its lower portions and connected at all upper corners, and other places of near approach, to a metallic roof from which in turn conductors extended above the chimney tops and other protrusions, would, therefore, appear to be especially well protected from lightning damage.

A stone or wooden building should have electrically continuous rods up each corner to the eave, thence to and along the ridge, with such side branches and elevated projections as the size and shape of the building, and other considerations, may require. In general, no place on the roof should be more than 3 meters (10 feet) from some portion of the protective system. Further, the principal and secondary conductors must be so placed that from any point the ground may be reached by a continuous *downward* course.

Protection would also be increased by surmounting each corner with a conducting rod 3 to 4 meters tall, properly connected to the rest of the system. Architectural considerations, however, might often forbid this additional precaution.

JOINTS.

To facilitate the discharge as far as possible the conductors should be as nearly as practicable continuous. Hence all necessary joints should be electrically good and mechanically secure. Well-made screw joints turned up tight appear to be the best.

BENDS.

Since electric surges tend to arc across sharp angles lightning rods must have no short bends. Changes in direction must be avoided as far as possible and wherever necessary be made gradually along a curve of 30 centimetres (one foot) radius, or more,—self induction must be kept at a minimum.

ATTACHMENT.

The rods should be attached to the building with holders of the same material as the rod itself. This prevents corrosion, and also secures electrical connection to the roof and sides which usually are wet and conducting during a thunderstorm.

GROUND CONNECTIONS.

Because of the considerable resistance of even very damp earth, ground connections should be as good and as many as practicable. Every descending rod, and there would better be one at each corner, and on large buildings even more, should be sunk straight down to perpetually damp earth, if convenient connected also to underground water pipes, and of course protected from injury a couple of meters above ground. Generally copper is best for this purpose. If iron is used it should not be packed in coke or charcoal, since either would cause the iron more rapidly to corrode.

CONNECTION TO NEIGHBORING CONDUCTORS.

The high potential and strong induction of the lightning discharge require that not only gutters, waterspouts, and the like, on the outside, but also all internal conductors of large size or considerable length be connected with the outer system at their upper ends and wherever they come within even two or three meters of it, cross connected with each other at points of close approach, and, finally, well grounded, from their lower ends, either directly or by proper attachment to the main conductors.

It is often stated that leaky gas pipes should be excepted from such connections. Possibly so, but in the first place gas pipes should not be allowed to leak.

SPECIAL DANGERS.

Overland wires, telephone, telegraph, light and power, necessarily are sources of danger unless provided with proper lightning arresters. However, appropriate devices of this nature commonly are installed, and therefore danger from electric wires usually is negligible. Nevertheless, it must be remembered that this distinctly is a case where the price of protection is proper forethought and adequate precaution.

A much greater source of danger, because seldom if ever provided with an efficient lightning arrester, is the harmless-looking wire clothes line running from some part of the house to a convenient tree. The obvious remedy in this important case is either to use a cotton or other fiber rope, or else to avoid connection with the house altogether.

Still another common source of danger, especially to stock, is the ordinary wire fence. But here, too, approximate safety is easy of attainment. It is only necessary that good ground connections be made at intervals of every 100 meters (20 rods), or less—the shorter the better, so far as safety is concerned.

Finally the question of shade trees is of some importance. None is safe, but in general the danger they imply increases both with their own height and with the elevation of the ground above adjacent regions.

CHAPTER XV.

ATMOSPHERIC ELECTRICITY

THREE manifestations of atmospheric electricity, lightning (discussed in connection with the thunderstorm), the aurora polaris, and St. Elmo's fire—a "brush" discharge from elevated objects—have long been known; the first two, of course, from the beginning of human existence, and the last, as an object of the sailor's superstition, certainly since the days of ancient Greece and Rome.[128] Their identification, however, as electrical phenomena is very modern.

The following list of contributions to the science of atmospheric electricity, though fragmentary, will, perhaps, give some idea of its slow but accelerated course of development:

(*a*) The suspicion of the electrical nature of lightning by Hawksbee, who says,[129] "Sometimes I have observed the light to break from the agitated [electrified] glass in as strange a form as lightning." And also,[130] "I likewise observed that . . . it was but approaching my hand near the surface of the outer glass [a rotated open receiver containing an exhausted vessel] to produce flashes of light like lightning in the inner one": by Wall.[131]

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[128] Brand's "Antiquities," Castor and Pollux.

[129] *Phil. Trans.*, 1705.

[130] *Phil. Trans.*, 1707.

[131] *Phil. Trans.*, 1708.

. . . "by holding a finger a little distance from the [electrified] amber, a crackling is produced, with a great flash of light succeeding it . . . and it seems, in some degree, to represent thunder and lightning"; by Gray[132] . . . "this electric fire, which, by several of these experiments, seems to be of the same nature with that of thunder and lightning"; and by many others.

(*b*) The devising by Franklin,[133] in 1749, of a simple means "to determine the question, whether the clouds that contain lightning are electrified or not."

(*c*) The proof, May 10, 1752, by d'Alibard[134] (following Franklin's suggestion), that clouds in which lightning appears are electrified.

(*d*) The proof, July, 1752, by Le Monnier[135] that a tall, insulated metallic conductor becomes electrified even when the sky is absolutely clear.

(*e*) The inauguration in 1757 by Beccaria[136] of systematic and long continued (15 years) observations of atmospheric electricity.

(*f*) The invention by Thomson[137] (Lord Kelvin) of the quadrant electrometer in 1855, and the "water-dropper," about the same time, that greatly increased the delicacy and accuracy of the measurements of atmospheric electricity.

(*g*) The discovery by Linss[138] in 1887 that even the most perfectly insulated conductors lose their charges, when exposed to the air, in a manner that shows the atmsophere itself to be a conductor of electricity.

(*h*) The discovery in 1900 by C. T. R. Wilson[139] and also by H. Geitel[140] of spontaneous ionization in the atmosphere.

(*i*) The discovery in 1902 independently by Rutherford and Cook,[141] and McLennon and Burton,[142] of a penetrating radiation in the lower atmosphere, presumably from radioactive substances near the surface of the earth.

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[132] *Phil. Trans.*, 1735.

[133] "Experiments on Electricity," edition 1769, p. 66.

[134] Franklin, "Experiments on Electricity," edition 1769, p. 107.

[135] *Acad. Roy. des. Sciences*, 1752, p. 233.

[136] "Dell' Elettricità Terrestre Atmospherica a Cielo Sereno," Torino, 1775.

[137] *B. A. Rept.*, 1855 (2), p. 22.

[138] *Met. Zeit.*, **4**, p. 345, 1887.

[139] *Proc. Cambr. Phil. Soc.*, **2**, p. 52, 1900.

[140] *Phys. Zeitsch.*, **2**, p. 116, 1900.

[141] *Phys. Rev.*, **16**, p. 183, 1903.

[142] *Phys. Rev.*, **16**, p. 184, 1903.

(*j*) The discovery in 1905 by Langevin[143] of slow moving or large ions in the atmosphere.

(*k*) The discovery by Simpson[144] in 1908 and 1909 that the electric charge on thunderstorm rain, and precipitation generally, is prevailingly positive.

(*l*) The discovery by Kolhörster[145] that an extremely hard or penetrating radiation exists in the atmosphere that comes from the outside—chiefly, apparently, from the sun.

ELECTRICAL FIELD OF THE EARTH.

The experiments of Franklin and others with kites and insulated vertical rods revealed a persistent difference of electric potential between the earth and the atmosphere, that soon became, and still is, the object of innumerable measurements.

Instruments.—The instruments essential for accurate measurements of the difference of potential between the earth and any point in the atmosphere are a " collector " and an electroscope. The " collector " is merely an insulated conductor provided with an adequate means of electric discharge—sharp point, flame, ionizing salt, or " dropper "—that brings it and all other conductors with which it is electrically connected to the potential in the air at the point of discharge.

The electrometer, one element of which is connected to the " collector " and thus brought to its potential while the other is grounded, or connected to a " collector " at a different level, may be any one of several types. Those generally used at present are the Thomson quadrant, Bendorf registering (adaptation of the Thomson quadrant), Wulf bifilar, and Einthoven single-fiber. The quadrant type must be kept stationary, but the others are not so restricted and give good results even on shipboard and in balloons.

Potential Gradient Near the Surface.—The vertical potential gradient near the surface of the earth varies greatly, with location, season, hour, and weather conditions—occasionally even reversing sign during storms—but the general average over level areas and during fine weather appears to be of the order of 100 volts per meter, in response to a negative surface charge.

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[143] *C. R.*, 140, p. 232, 1905.

[144] *Memoirs Indian Meteorl. Dept.*, Simla, 1910, 20, pt. 8.

[145] *Deutsche Phys. Gesel.*, July 30, 1914.

Location Effect.—Since the earth is a conductor it is obvious that the distribution on its surface and the resulting vertical potential gradient will be so modified by topography as to be smaller in narrow valleys than on the neighboring ridges. Over level regions of the same elevation the gradient appears to be largest in the interior of continents of the temperate zones and least within the tropics, and also, perhaps, in very high latitudes.

Annual Variation.—The annual variation of the vertical potential gradient near the surface of the earth differs greatly from place to place. In general it is comparatively small in tropical regions, and also anywhere on mountain tops, but large, as much in some cases as twice the annual average value, in the temperate zones where the gradient changes are roughly as follows: An increase during the fall and early winter to a maximum of perhaps 250 volts per meter, followed by a rapid decrease during spring to a moderately constant summer minimum of roughly 100 volts per meter.

Diurnal Variation.—The diurnal variation of the potential gradient, in some places fully equal to the average gradient, changes with place, season, and altitude. Its amplitude is greater along middle latitudes in the interior of continents than along low latitudes, or anywhere over the ocean; greater during winter, when it is single-crested, than summer, when double-crested. At moderate elevations, half a kilometer or less, the gradient has only a single daily maximum and minimum, whatever its surface periods.

In all cases a minimum gradient occurs about 4 o'clock in the morning. If the variation is double diurnal the second, but less pronounced minimum, occurs about mid-afternoon; the first maximum at 9 o'clock, roughly, in the forenoon, and the second at about 8 to 9 o'clock in the evening. If the variation is only diurnal, as in the winter, the maximum is attained during afternoon. Typical examples of such curves are given in Fig. 118 after Bauer and Swann.[146]

From the above facts it appears that the single daily variation of the potential gradient is fundamental, and that the summer afternoon minimum that develops a double diurnal variation is only a shallow disturbance due, presumably, in part at least, to dust, since any material caught up from the earth obviously must carry along some of the negative surface charge and thereby decrease the gradient in the lower air.

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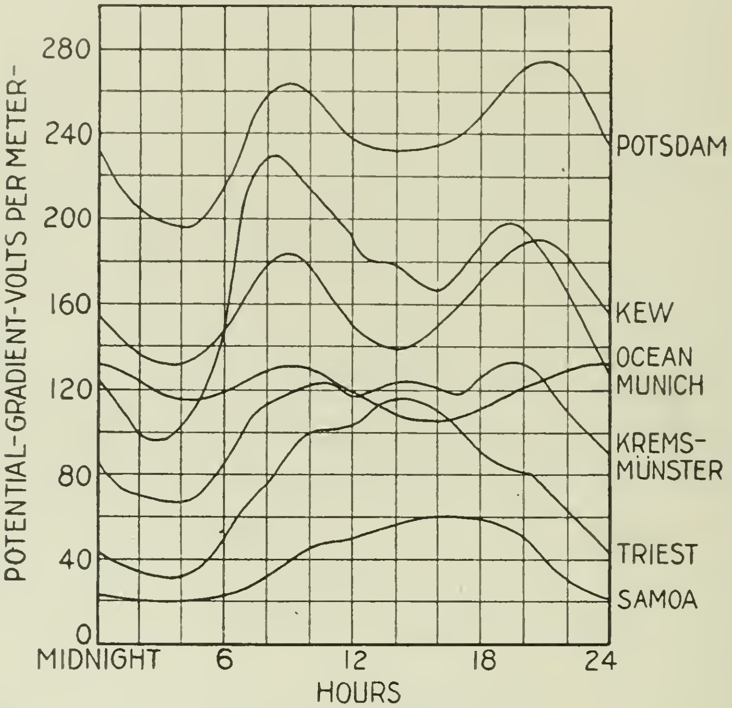
[146] Publication No. 175 (Vol. III) of the Carnegie Institution of Washington.

Potential Gradient and Meteorological Elements.—Many efforts have been made to find what relations obtain between the potential gradient and the various meteorological elements, but the results in most cases are inconclusive, especially in respect to temperature, humidity, and pressure changes. Strength and direction of wind both are important through their effect on the amount of smoke, dust, factory fumes, et cetera, in the air at the place of measurement. Fog, rain, and other forms of precipitation are nearly always electrically charged and therefore often greatly modify and occasionally even reverse the potential gradient as do also heavily charged or thunderstorm clouds. Cirrus and other types of high, fair-weather clouds produce little or no effect.

FIG. 118.



Diurnal variation of potential gradient.

Potential Gradient and Elevation.—Measurements of the potential gradient from free balloons have shown that it varies greatly and irregularly through the low dust-laden stratum, and that above this layer it decreases less and less rapidly to a comparatively small value at an altitude of only a few kilometers. If the surface gradient is 100 volts per meter, it may be 25 volts per meter at an elevation of 1.5 kilometers, 10 at an elevation of 4 kilometers, 8 at 6 kilometers elevation, with similar decreases for greater heights.

Surface and Volume Charges, et cetera.—From the simple equation,

$$\frac{dN}{dn} = \frac{100 \text{ volts}}{\text{meter}} = f = 4\pi\sigma,$$

giving the electric force, *f*, or rate of change of potential normal to the surface, in terms of the surface charge σ per unit area, it follows that when the potential gradient at the surface of the earth is 100 volts per meter the charge is 2.65×10^{-4} negative electrostatic units per square centimeter, or 4.5×10^5 coulombs, roughly, for the total surface charge of the earth.

Similarly, from the equation,

$$\frac{d^2V}{dn^2} = \frac{df}{dn} = 4\pi\rho$$

between the volume charge ρ and the ratio of change of the electric force to change of elevation, it appears that near the surface of the earth the net charge of the air is roughly 0.1 electrostatic unit of positive electricity per cubic meter.

ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE

It is well known that an electrified conductor exposed to the air gradually loses its charge, however carefully it may be insulated. This phenomenon was first investigated by Coulomb,[147] who found the important law that the rate of loss of charge is proportional to the existing charge, or rate of drop of potential proportional to the existing potential. In symbols,

$$\frac{dQ}{dt} = -aQ \text{ and } \frac{dV}{dt} = -aV$$

or

$$Q_t = Q_0 e^{-at}$$

and

$$V_t = V_0 e^{-at}$$

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[147] *Mém. de l'Acad. de Paris,* 1785, p. 616.

where Q_0 and V_0 are the charge and potential, respectively, at any given instant, Q_t and V_t the corresponding values t seconds, or other units of time, later, e the base of the natural logarithms, and a a constant.

The loss of charge was explained by Coulomb, and his explanation was accepted for more than a century, as due to the charging by contact of neutral molecules of air and their subsequent repulsion.

From the work begun by Linss[148] and extended by others it is now known, however, that the discharge coefficient a varies more or less from hour to hour and from season to season, and, further, that generally it is not the same for charges of opposite sign. Hence the loss of charge in addition to that which may be accounted for by imperfect insulation, is due to neutralization by numerous minute charges of the opposite sign normally present in the atmosphere—charges that render it conductive. It is also known that the values of these charges are either that of the electron or multiples thereof. Swann[149] has shown that whatever the shape of the charged body the rate of its loss of charge is given by the equation,

$$\frac{dQ}{dt} = -4\pi Q n e v$$

where Q is the charge on the object, n the number of ions per cubic centimeter of sign opposite to that of Q, v the specific velocity of these ions and e the ionic charge. In other words, the rate of supply of electricity by the ions to the charged body is $4\pi\lambda\ C\ V$, in which C is the capacity of the charged object and λ the conductivity of the air for electricity of sign opposite to that of the charge.

The conductivity, therefore, of the atmosphere may be conveniently measured by noting the rate of potential drop of a charged cylinder concentrically surrounded by a relatively large tube through which a good circulation of fresh air is maintained. Fig. 119 indicates the equipment used for this purpose on the *Carnegie* during the cruises of 1915–1916.[150] As explained in the publication referred to, if C_1 is the capacity of the whole apparatus, including the electroscope, and C_2 the measured capacity of the concentric cylinders, including that portion of the supporting rod A that is exposed to the air current, then

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[148] *Met. Zeit.*, 4, 345 ,1887.

[149] *Terr. Mag. and Atmos. Elec.*, 19, p. 81, 1914.

[150] Bauer and Swann, Publication 175 (Vol. III) of the Carnegie Institution of Washington, p. 385.

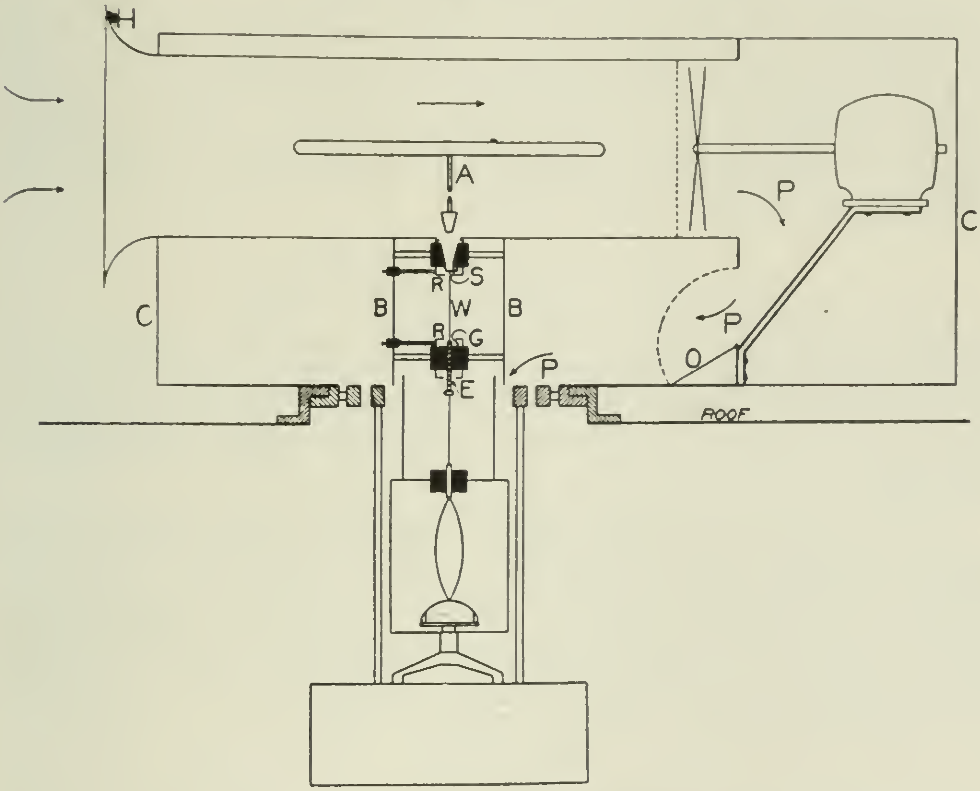
$$-C_1 \frac{dV}{dt} = 4\pi\lambda C_2 V$$

and

$$4\pi\lambda C_2 = \frac{C_1}{T} \log_e \frac{V_1}{V_2}$$

in which T is the time required for the potential to fall from V_1 to V_2. Hence both conductivities, λ_+ and λ_-, corresponding respectively to the positive and negative ions, are easily determinable.

FIG. 119.



Conductivity apparatus.

The average value of the conductivities found during the above-mentioned cruise of the *Carnegie* were $\lambda_+ = 1.44 \times 10^{-4}$ and $\lambda_- = 1.19 \times 10^{-4}$. These are also approximately the values found over land during clear weather.

Annual Variation.—In general the conductivity is greater during the summer than during winter—the reverse of the potential gradient.

Diurnal Variation.—The diurnal variation of the conductivity is quite irregular, but is more or less the reverse of the potential gradient, that is, high in the early morning and low in the evening.

Relation to Weather.—The conductivity of the atmosphere is very small when the air is either dusty or foggy; nearly all the ions being then attached to masses so large that the velocity factor, v, in the current equation, and consequently the current itself, is quite small. On the other hand, when the air is clean and dry, the conductivity is relatively large.

Conductivity and Elevation.—Through the first kilometer the conductivity of the atmosphere varies irregularly, owing, presumably, at least in part, to corresponding variations in the dust content. Beyond about that level it generally increases rather rapidly, so that at the elevation of 6 kilometers it may have roughly 20 times the surface value.

IONIC CONTENT OF THE AIR

Ionic Density.—The number of ions of either sign per unit volume of the atmosphere may be found by passing a known volume of air through a cylindrical condenser, sufficiently charged to catch all the ions of opposite sign, and noting the drop in potential.

Let n_+ and n_- be the number of positive and negative ions respectively per cubic centimeter of the air examined, e the ionic charge, V the initial potential, and δV the drop in potential on passage of A cubic centimeters of air through the condenser, then, neglecting, or allowing for the leakage,

$$n_\pm = \frac{C \delta V}{e A}$$

The value of n varies greatly, being very small during foggy and dusty weather, and relatively large when the air is clear. In general it is larger during summer than winter, larger during the day time than at night, and larger when the temperature is high than when it is low. It also increases with elevation through at least the first few kilometers, but to what maximum value, and where, is not known.

Through the lower atmosphere the fair-weather values of n_+ and n_- generally are of the order of 800 and 680, respectively, per cubic centimeter.

Ionic Velocity.—The velocities v_1 and v_2, of the positive and negative ions respectively, may be computed from the corresponding values of the current, $n_{+}ev$, and ionic density n_{+}, since the value of e is a known constant. The average value of v_{+} in the lower air is of the order of $1 \frac{\text{cm/sec}}{\text{volt/cm}}$, and of v_{-} $1.2 \frac{\text{cm/sec}}{\text{volt/cm}}$. Both values increase with decrease of pressure—at half the pressure the velocity is double, approximately—and therefore with increase of elevation.

Large, or Langevin Ions.—After the atmosphere is deprived of all its ions of molecular size it still is slightly conductive, because, as discovered by Langevin,[151] of the presence of relatively slow moving and therefore comparatively massive ions. The number of such ions per cubic centimeter varies greatly. In the open country this number appears to be comparatively small, but it is very great over large cities, perhaps many times that of the ordinary or molecular ions.

ELECTRIC CURRENTS IN THE ATMOSPHERE

At least four different electric currents exist in the atmosphere—two always and everywhere, or nearly so, and two sporadically in time and place. These are:

(a) The lightning discharge, of very brief duration, but often rising to a strength of many thousand amperes.

(*b*) Precipitation currents, or currents due to the falling of charged rain, snow, hail, et cetera. The average strength of such current may be found from the rate of precipitation and charge, usually positive, per cubic centimeter, say, of the rain, or its equivalent in the case of snow or hail. During non-thunderstorm rains this current often averages about 10^{-16} ampere per square centimeter of surface. During violent thunderstorms, however, it is far greater, even as much as 10^{-12} ampere per square centimeter for brief intervals has been reported.

(*c*) Convection currents, due to the mechanical transfer of the ions in the atmosphere from one place to another by winds, including vertical convection. The strength of such current per unit area at right angles to the direction of the wind is obtained by multiplying the wind velocity by the net density of the charge.

This density may be found either by multiplying the ionic charge by the difference between the numbers of ions of opposite sign per cubic centimeter, or from the equation,

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[151] *C. R.*, 140, p. 232. 1905.

$$\rho = -\frac{1}{4\pi} \frac{d^2 V}{d h^2}$$

in which ρ is the density required, and dV/dh the vertical potential gradient.

The value of ρ varies greatly, but through much of the atmosphere the convection current is of the order 10^{-16} ampere per square centimeter cross section of the wind, per meter/second velocity.

(*d*) Conduction current, due to the downward flow of one set of ions, usually the positive, and the simultaneous upward flow of the other in response to the vertical potential gradient. The density of this current, or strength per square centimeter cross section, may be computed from the potential gradient and the conductivity, or, with suitable apparatus, may be measured directly. The average value of this conduction current is of the order of 3×10^{-16} ampere per square centimeter of, apparently, the entire surface of the earth. It generally is less during the day than at night, and less in summer than winter; but always of such value that the sum total of the current for the entire earth is roughly 1500 amperes. How this constant current, always, on the whole, in the same direction, is maintained is one of the greatest problems of atmospheric electricity.

RADIOACTIVE CONTENT OF THE ATMOSPHERE

The first evidence that the atmosphere normally contains one or more radioactive substances was obtained in 1900 when Geitel[152] and C. T. R. Wilson [153] independently found than an insulated electrified conductor gradually loses its charge even when inside a closed vessel. Later Elster and Geitel[154] showed that a bare wire exposed to the air and charged negatively to a high voltage gradually becomes coated with radioactive material. In 1904 Bumstead[155] showed that the radioactive substance of the atmosphere consists essentially of radium and thorium emanations, which, it is now known, occur in widely varying proportions. On the average, however, they appear to produce about the same amount of ionization, that is, near the surface and over land, roughly 2 ions each, of each sign, per cubic centimeter per second.

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[152] *Phys. Zeit.*, 2, p. 116, 1900.

[153] *Proc. Camb. Phil. Soc.*, 2, p. 52, 1900.

[154] *Phys. Zeit.*, 2, p. 590, 1901.

[155] *Amer. Jr. Sci.*, 18, p. 1, 1904.

The emanations, which are heavy, radioactive gases, are several fold more abundant in mines and cellars than in the open and obviously get into the atmosphere by diffusion from the earth where they are generated by the spontaneous decomposition of radium and thorium. They may be absorbed from a known volume of air by coconut charcoal, liquified by low temperatures (–150° C. or lower), or caught up by a conductor charged to a high negative potential. In any case the nature of the deposit can be determined from the decay curve, from which, together with the saturation current and the volume of air used, the amount of active material per unit volume may be determined. In this way it has been found[156] that the radioactive emanations in the atmosphere over the Pacific Ocean, Sub-Antarctic Ocean, and land (average) amount to 3.3×10^{-12}, 0.4×10^{-12}, and 88×10^{-12} curie per cubic meter, respectively. Or, since the volume of one curie of emanation at standard temperature and pressure is 0.59 cubic millimeter,[157] the emanation gases constitute, in these several regions, 1.95×10^{-19}, 0.24×10^{-19}, and 51.9×10^{-19} of the atmosphere, respectively.

The amount of these emanations appears to be sufficient to account for the measured ionization (ions of molecular size) on the land, but quite insufficient over the oceans to maintain the ionization of these regions. Perhaps, as the slow ions are so very numerous over land areas, it may account for only a small part of the ionization in either case.

PENETRATING RADIATION

It has been found that the air within a closed metallic vessel remains fully conductive, even when deprived of all emanations and when the inner walls of the vessel have been cleaned, as far as possible, of radioactive materials. By surrounding this vessel with thick screens, or sinking it in water, the conductivity of the enclosed air is more or less reduced.[158] It is, therefore, inferred that the conductivity in question is produced by penetrating radiation of the γ type from the outside. One obvious source of such radiation is the radium and thorium, and their decomposition products, that seem to be more or less prevalent everywhere near the surface of the earth, especially over land.

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[156] Bauer and Swann, Publication 175 (Vol. III) Carnegie Institution of Washington, p. 422.

[157] Rutherford, "Radioactive Substances and Their Radiations," Cambridge University Press, 1913, p. 480.

That a portion at least of the ionization giving this conductivity is produced by the γ rays of ordinary radioactive substances in the earth and lower atmosphere is evident from the fact that it decreases with elevation up to about 1.5 kilometers above the surface. From this level, however, up to the greatest elevation at which it has been reported, 9 kilometers, the ionization increases very rapidly, and to several fold its surface value.[159] Hence there appears also to be a γ radiation of extremely high penetrating power that enters the lower atmosphere from somewhere above it.

ORIGIN AND MAINTENANCE OF THE EARTH'S CHARGE

Numerous hypotheses have been made to account for the negative charge of the earth and to explain how that charge is maintained in spite of the conductivity of the atmosphere, but no satisfactory explanation of either has yet been found. As Simpson[160] has explained, since the vertical current is constant up to at least 1800 meters, the greatest altitude at which it has been determined, it follows that the negative charge of the earth can not be supplied from the air below that level. Neither can it be supplied by electrical separation within the earth, as that would quickly lead to a positive instead of the prevailing negative surface charge.

Simpson[161] suggests that the negative charge of the earth may be maintained by a bombardment from the upper atmosphere, or even cosmical space, of negative ions of much greater penetrating power than any now known. But, it is stated, this is only a suggestion and not a solution of the greatest, perhaps, of the problems of atmospheric electricity.

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[158] Rutherford and Cook, *Phys. Rev.*, 16, p. 183, 1903; McLennan and Burton, *Phys. Rev.* 16, p. 184, 1903.

[159] Kolhörster, *Deutsch. Phys. Gesell.*, 16, p. 719, 1914.

[160] *M. W. R.*, 44, p. 115, 1916.

[161] *Loc. cit.*

The latest and most satisfactory explanation of the origin of the earth's charge is the following, by Swann[162]:

"Measurements of the variation of the penetrating radiation, with altitude, point to the upper atmosphere as the origin of a part of this radiation. The whole of the penetrating radiation is probably of the γ-ray type, but the part which reaches the earth's surface from the outer atmosphere is naturally the most penetrating part. Indeed, it is so penetrating that it passes through a thickness of air which would be equivalent, in absorptive action, to a column of mercury 76 cm. high, if absorption coefficients were simply proportional to density and were independent of material. The γ-ray radiation from the outer layers of the atmosphere will consequently be very 'hard,' and, in accordance with the known results of laboratory experiments, we must conclude that the negative corpuscles which it emits from the air molecules are emitted almost entirely in the direction of the radiation, and further, that they can have a range in air at least equal to that of the swiftest β-rays from radium products, a range, for example, of 8 meters. The emission of corpuscles by these γ-rays will consequently result, at each point of the atmosphere, in a downward current of negative electricity, which we shall call the corpuscular current. This corpuscular current will charge the earth until the return conduction-current balances the corpuscular current at each point of the atmosphere.

"Taking, for the purpose of this abstract, a simplified case where the penetrating radiation considered is all directed vertically downwards, if q is the number of corpuscles liberated per c.c. per second by the penetrating radiation and h the average distance which a corpuscle travels from its point of origin, the corpuscular current density will be

$$i = qeh,$$

where e is the electronic charge.

"If q be taken as 2, which is probably about equal to the number of pairs of ions produced per c.c. per second in a closed vessel as a result of the part of the penetrating radiation in question, and if h be taken as 8 meters, we have

$$i = 2 \times 4.8 \times 10^{-10} \times 800 = \text{about } 8 \times 10^{-7} \text{ E. S. U./cm.}^2,$$

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[162] *Phys. Rev.*, 9, p. 555, 1917.

which is just of the order of magnitude of the air-earth current density, so that on this view, the penetrating radiation from the outer layers of the atmosphere provides a sufficient basis for the explanation of the maintenance of the earth's charge.

"The corpuscular current-density, and consequently the conduction current-density, will not necessarily be independent of the altitude, for the factors upon which *i* depends, viz., the intensity and quality of the penetrating radiation, the number of molecules per c.c. available for possible ionization by the radiation, and the range of the corpuscles set free all alter with the altitude.

"A few minor difficulties present themselves if the above view be adopted. Thus, for example, near the surface of the earth, a considerable portion of the whole penetrating radiation comes from the soil, and is directed upwards, but this difficulty disappears when it is remembered that the average 'hardness' of the radiation from the soil is very much less than that of the radiation which reaches the earth from the outer layers of the atmosphere. Again, it might appear that the corpuscles set free by the pentrating radiation should, on account of their great energy, produce in the atmosphere many more ions per second than are actually found to be produced. This difficulty, and others of allied nature become greatly reduced in magnitude, however, when considered in the light of our present knowledge of the action of very swift β-rays when passing through a gas."

(*To be concluded.*)

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY*

THE NATURE OF A DEVELOPER SLUDGE.[1]

By Mr. J. I. Crabtree.

[ABSTRACT]

A SAMPLE of a sludge taken from a deep tank pyro developer compounded with sodium bisulphite was found to consist mainly of fine needle shaped crystals of calcium sulphite corresponding to the formula $CaSO_3\ 2H_2O$.

In order to explain the presence of the calcium salt it was at first assumed that some compound of calcium had been accidentally added to the developer, or that some of the ingredients contained calcium as impurity, but as only pure chemicals were employed it was concluded that the calcium must have been originally present in the water used for compounding the developer.

On adding a definite amount of calcium in form of chloride or sulphate to water used for mixing the developer, it was found that the presence of .025 per cent. dry calcium chloride was sufficient to assure the formation of crystals of calcium sulphite, if the solution containing the sulphite and bisulphite was allowed to stand before adding the carbonate.

Calcium sulphite is soluble in an excess of sodium bisulphite forming calcium bisulphite, but on allowing this solution to stand in the air needle shaped crystals of $CaSO_3\ 2H_2O$ are deposited.

The absence of magnesium from the sludge in question was due to the relatively high solubility of magnesium sulphite and magnesium carbonate in a solution of sodium carbonate.

Although a number of trials were made by compounding the complete developer with water containing calcium salts, in no case were needle shaped crystals deposited on standing, only a semi-amorphous sludge being precipitated. It was considered that the needles could only have crystallized within the complete developer if it were very warm.

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*Communicated by the Director.

[1] Communication No. 62 from the Research Laboratory of the Eastman Kodak Company, published in *British Journal of Photography,* 1918, p. 87.

The presence of a sludge such as the above in a developer is harmless if allowed to settle, though the developer is robbed of sulphite to the amount required to form the sludge. If the developer is agitated, the sludge is apt to cause trouble by settling on the emulsion of the plates or films, though it may be removed by filtering.

In case the calcium is present as bicarbonate, thus causing temporary hardness of the water, the formation of the sludge may be prevented by boiling the water and allowing it to cool previous to compounding the developer. If the calcium is present as chloride, or sulphate, in which case the water is permanently hard, this may be removed by precipitating with sodium or potassium oxalate or sodium carbonate. The oxalate treatment will also remove temporary hardness.

Tests showed that the oxalate had no effect on the fogging power of the developer when present even to the extent of 1 per cent., so that a little excess of oxalate during precipitation will do no harm.

Mica Schist for Furnace Lining. G. F. LOUGHLIN. (*U. S. Geological Survey.*)—Mica schist is one of the commonest kinds of metamorphic rock and consists essentially of mica and quartz, with which may be associated certain other minerals, such as garnet and staurolite. Owing to its marked foliation, its softness, and its generally unattractive appearance, it has not been greatly used as structural stone or as paving or crushed stone. It was once quarried near Bolton, Conn., for use as flagstone, but it was too soft to withstand the wear upon it in places of much travel.

The mica, to which the softness of mica schist is due, however, successfully withstands a very high temperature, and as the stone can be readily cut into blocks of the desired shape, mica schist has therefore been used considerably as furnace lining. The mica schist quarried for this use is found in eastern Pennsylvania, at places conveniently near the metallurgical plants in which it is required. The quantity of mica schist produced for this purpose in 1917 was 39,975 short tons, an increase of 6739 tons, or 20 per cent., over 1916. The value of the output in 1917 was $85,986, an increase of $38,682, or nearly 82 per cent. The greater increase in value was due to a rise in price from $1.42 to $2.15 a ton, which largely represents the increased cost of production.

NOTES FROM THE RESEARCH LABORATORY WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY*

THE ACTION OF REDUCING GASES ON HOT SOLID COPPER.

By Norman B. Pilling.

THE deterioration in mechanical strength experienced by copper containing disseminated oxide after heating in contact with reducing gases is marked; a copper strap, initially ductile and resistant to repeated bending, after exposure of this kind becomes weak and friable, breaking when an attempt is made to bend it. Copper straps heated in atmospheres of hydrogen, carbon monoxide and natural gas all developed this defect, the severity of this action depending on the nature of the reducing gas. In the case of hydrogen the first mechanical effects of the deterioration appear between 400 and 500°C, and at temperatures above 700°C the action is very rapid, a few minutes' exposure being sufficient to ruin the strap.

Deoxidation alone cannot account for the weakness developed, for it is hard to see why the substitution of a small void for a small particle of very brittle cuprous oxide would weaken the surrounding copper. The action taking place appears to be that hydrogen, if physically soluble in the copper, would diffuse into the metal, attack and reduce the grains of cuprous oxide with the formation of steam. If steam is physically less soluble in solid copper, the net result of the reaction would be the formation of a quantity of steam free within the voids left by the reduction of the cuprous oxide and at some considerable pressure. The combination of this pressure with the known intercrystalline weakness of copper at high temperatures would force the individual grains apart until relief is obtained, and the resultant weakness be due simply to the lack of mechanical coherence within the "puffed" copper. Microscopic examination of copper after this treatment disclosed intercrystalline fractures, and the swelling action accompanying their formation increased the physical dimensions of the copper piece.

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*Communicated by the Director.

To verify the explanation given, the diffusion of hydrogen, steam, carbon monoxide and carbon dioxide through copper was measured. A thin walled copper tube extended through a quartz tube filled with the desired gas, and the changes in pressure within the previously evacuated copper tube were measured with an optical-lever manometer. At 700°C the following comparative rates were obtained, referred to hydrogen as 1000:

Gas	Diffusion rate
H_2	1000
H_2O	65
CO	17
CO_2	0.6

With hydrogen the first considerable diffusion began between 400 and 500°C, corresponding to the initial deterioration in physical quality noted. Measurements of the rate of diffusion of hydrogen were also made by noting the depth to which the reduction of the oxide had occurred in solid pieces of copper. By this method diffusion was also found to become active between 400 and 500°C.

The distribution of the oxide particles in copper is a more important factor than their total quantity. In wrought copper the particles are uniformly dispersed throughout the grains, and only those lying by chance at the grain boundaries are operative in forming intercrystalline fractures. Cast copper, in which the oxide is segregated as a eutectic at the grain boundaries, is extremely susceptible to hydrogenation.

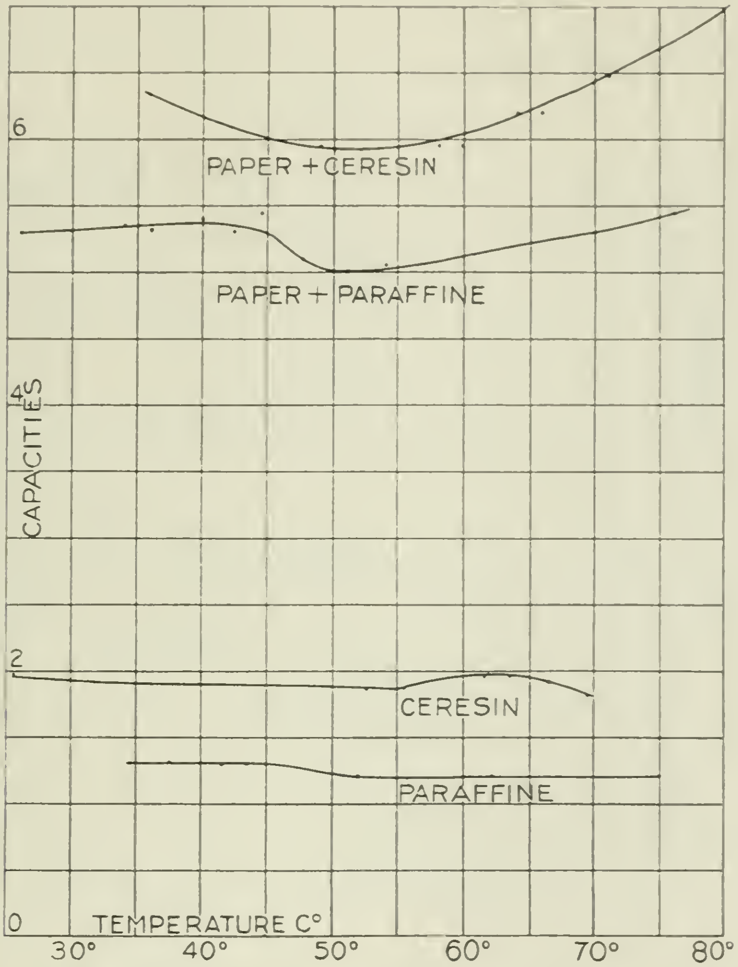
CHANGE OF SPECIFIC INDUCTIVE CAPACITY WITH TEMPERATURE AND IMPREGNATION IN PAPER.

By H. C. P. Weber and T. C. MacKay.

THE object of this work was to obtain preliminary information on a number of materials. The first measurements were made by a substitution form of series resistance method, with high frequency generator and telephone. Silence in telephone was difficult to obtain due to harmonics. An Einthoven galvanometer proved less sensitive to changes in the resistance and the eye strain in the detection of very small currents is great.

In order to make a large number of measurements to determine quickly the order or magnitude of the specific inductive capacities, the simple bridge method in which two arms are resistances and the other two capacities was used. In this bridge R_1 and R_2 each are 9000 ohms. C_s is the condenser containing the sample, and C a calibrated air condenser. The sample holder consisted of two massive iron electrodes kept at a definite separation by small glass stops. The capacity of the sample holder as an air condenser was calculated from the dimensions to the 0.000185 m. f. and found by measurement to be 0.000202. Temperatures were taken as those of the massive iron container.

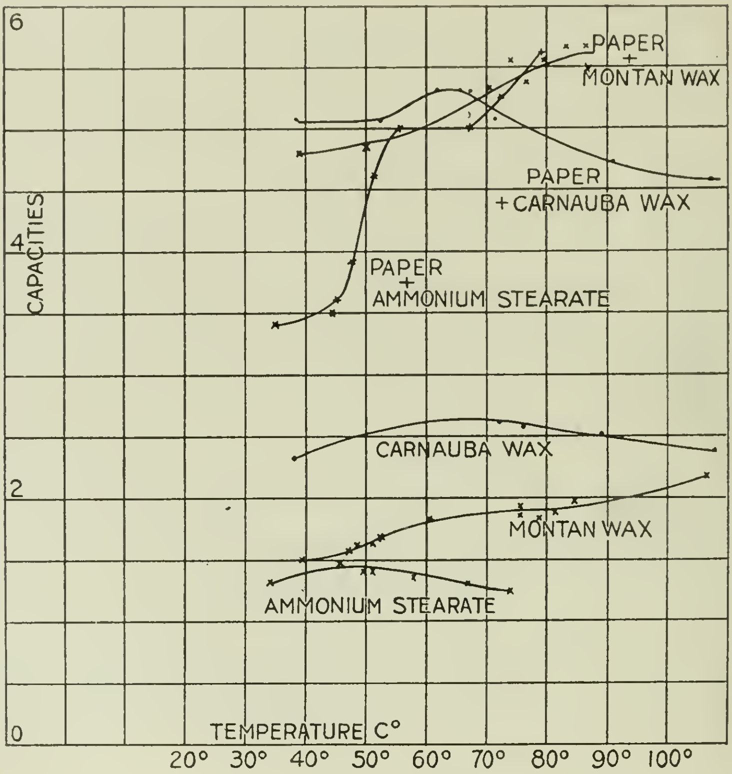
Fig. 1.



In the cases where impregnated paper was measured three layers 0.0015 inch thick were used. Impregnation changed the thickness of the paper 10–35 per cent., depending upon the nature of the substance. This change was measured where possible. In the case of dielectric without paper the thickness of the layer was about 0.01 inch, *i. e.*, that of the glass stops.

The curves in Figs. 1 and 2 show the values obtained with varying temperature. The specific inductive capacities of all of the substances tried is much higher in conjunction with the impregnated paper than alone. Most of the materials show a decided change in the neighborhood of the melting point. The two hydrocarbons—paraffin and ceresin—show little change alone; in paper a decided minimum is shown, with a gradual rise beyond the melting point. For the acids and acid derivatives—Carnauba wax, montan wax and ammonium stearate—there is again an appreciable difference between the values for pure substance and substance with paper. The values for pure material are, however, influenced

FIG. 2.



less by temperature changes. In the paper-impregnated samples there is a maximum or a decided hump in the curve.

In general a very decided change in the specific inductive capacities of materials is seen to accompany change of state of materials. The direction of the change seems to bear a definite relation to the composition. Further work would seem desirable along this line in order to determine the cause of this behavior.

A NULL BALLISTIC METHOD FOR COMPARING CAPACITIES.

By Dr. Phillips Thomas.

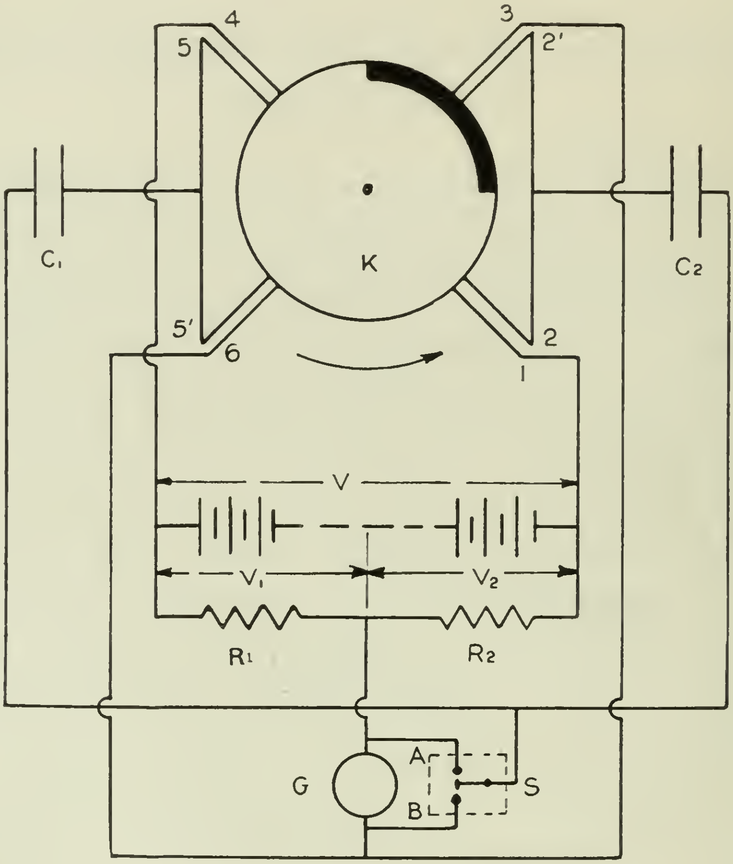
IN the course of some work on the dielectric properties of various chemical combinations, it was found that the preparation of more than a few cubic centimeters of the compound was undesirable until some preliminary knowledge of its properties had been obtained. Consequently, it became necessary to measure with fair accuracy capacities of the order of 10^{-9} to 10^{-11} farads.

It is possible to do this with considerable precision by any one of several methods, provided only that certan factors which enter as correction terms in the results be accurately known. The troublesome corrections involved, together with the fact that values were particularly desired at equivalent frequencies lower than those convenient for use with standard methods of test, led the writer to devise a simpler method, embodying only easily obtainable or readily constructed apparatus, with which the corrections should be easily determined and simple to apply.

The method arrived at, while not fundamentally new, has proved so serviceable and so surprisingly accurate that it is here offered for the consideration of others who may be confronted with similar problems.

The idea of measuring the absolute capacity of a condenser by the discharge through a ballistic galvanometer of a single impulse from the condenser is well known. So also is the modification in which the single impulse is replaced by a train of similar impulses produced by some form of commutator which permits only the charge or the discharge impulses, but not both, to reach the galvanometer. The capacity is given in terms of the current figure of merit or sensitivity of the galvanometer, the charging voltage and speed of the commutator. This method is applicable to very small capacities if the available charging voltage is sufficiently large. There remains, however, the difficulty of measuring accurately the commutator speed and the charging voltage, also the added and somewhat troublesome one of keeping both speed and voltage constant; also the galvanometer must be checked at frequent intervals, and finally all the disadvantages of a deflection method are present.

FIG. 1.



The present method is a modification of the above, in which the train of impulses from one condenser is balanced by a second train from a different condenser, passing through the galvanometer in the opposite direction. The apparatus and connections are shown in Fig. 1, in which K is the commutator, rotating counter clockwise as shown; C_1 is the condenser to be measured, C_2 a known condenser, usually a standard subdivided microfarad, R_1

and R_2 are standard dial rheostats. The commutator presents an insulating surface to the four sets of brushes, numbered 1 to 6, except for the solid segment, which latter is metal. The angle of the solid segment is 89°, and the brushes are set in pairs on 90° lines, so that no two pairs of brushes are ever interconnected.

As the commutator revolves it connects together in sequence, brushes 1 and 2, 2 and 3, 4 and 5, 5 and 6, and so on. If the switch S is closed in position A, the following cycle is completed once every revolution of the commutator. Left hand numbers indicate brushes connected.

1, 2 (1)–Condenser C_2 is charged to a voltage V_2, equal to $\frac{VR_2}{R_1+R_2}$

2′, 3 (2)–Condenser C_2 is discharged through the galvanometer, G.

4, 5 (3)–Condenser C_1 is charged to a voltage V_1, equal to $\frac{VR_1}{R_1+R_2}$

5′, 6 (4)–Condenser C_1 is discharged through the galvanometer in the opposite direction to that of the discharge from C_2.

Since the directions of the discharge impulses from C_1 and C_2 through the galvanometer are opposite, there will be no permanent deflection of the galvanometer light spot if the discharge impulses are equal. This condition is realized when R_1 and R_2 are so adjusted that

$$NC_1V_1 = NC_2V_2$$

or, since V_1 and V_2 are proportional to R_1 and R_2,

$$\frac{C_1}{C_2} = \frac{R_2}{R_1} \qquad (1)$$

By throwing switch S into position B the galvanometer receives the charge impulses instead of those of discharge. In testing samples, a balance is obtained for both charge and discharge; a difference of more than one per cent. between the indicated capacities shows that the results are not accurate to one per cent., due to different relative amounts of absorption, leakage, or both, in C_1 and C_2.

The result given by equation (1) is the comparative value of the total capacity in branches C_1 and C_2. This value must be corrected for the small permanent capacity in the two branches, when the condenser C_1 and C_2 are disconnected. The use of a large condenser on the C_2 side enables one to neglect this correction on that side; the correction for C_1 is easily applied by disconnecting C_1, obtaining a balance, and subtracting the indicated capacity from that found when C_1 is connected. Thus,

$$C_1 + c_1 = \frac{C_2 R_2}{R_1} \qquad C_1 \text{ connected}$$

hence

$$c_1 = \frac{C_2 r_2}{r_1} \qquad C_1 \text{ disconnected}$$

$$C_1 = \frac{C_2 R_2}{R_1} - \frac{C_2 r_2}{r_1}$$

If C_2 equals c_2, and R_1 equals r_1, we have

$$C_1 = \frac{C_2}{R_1}\left(R_2 - r_2\right) \tag{2}$$

which enables the correction to be made by simply subtracting the value of R_2 found with C_1 disconnected from that found with C_1 connected, and using the remainder in equation (1).

Obviously, the commutator speed for any capacity must not be high enough to prevent full charge from entering the condensers during one charging interval. Fortunately, satisfying this condition for C_1 also does so for C_2, because the resistance in the charging circuits are R_1 and R_2, and the two time constants, R_1C_1 and R_2C_2 are equal by equation (1), when balance has been established. This condition, however, sets an upper limit to the product NCR; in practice the maximum permissible speed corresponding to the desired product RC is taken from a curve kept with the apparatus.

The upper limit in capacity or voltage is set by the appearance of strong forced vibrations of the galvanometer moving system, due to the fact that the charging or discharging impulses, while equal, do not reach the galvanometer at the same instant, but are spaced a half revolution apart. The accuracy obtainable is of course decreased when the light spot is thus broadened out into a band of light. The lower limit of accuracy is set by the relative values of the residual or permanent capacity in the C_1 branch, and the capacity being measured.

The method is very easy to use, and its sensitiveness is limited only by the current sensitivity of the galvanometer. Small frictional voltages induced by the rotation of the commutator prevent the use of the most sensitive galvanometers obtainable, but a galvanometer of sensitivity 10^{-9}, current, is good in this respect and sufficiently sensitive to measure 10^{-10} farad of capacity to one percent. on a few volts.

The fact that neither voltage nor speed enters into the equation giving the results, makes it possible to obtain curves of variations of capacity with voltage and with equivalent frequency, since in most cases these coefficients of change are small, and one need not employ means for either closely controlling or very accurately reading either speed or voltage.

Neither the sensitiveness nor the accuracy is affected by the relative magnitude of C_1 and C_2, assuming that R_1 and R_2 are accurate over any range desired. Hence very small condensers may be compared directly with a large standard subdivided microfarad, in order either to calibrate the small or the large condenser. This is a great advantage and is possessed by none of the standard methods of testing. The writer uses, commonly, fixed values for C_2 and R_1, of 0.05 microfarad and 5000 ohms respectively, resulting in the convenient equation

$$C_1 = 10^{-11} (R_2 - r_2)$$

Rheostat R_2 has dials giving 10 x 0.1 and 9 x (1+10+100+1000). With C_1 disconnected the galvanometer is sensitive to one division on the 0.1 ohm dial with an e.m.f. (V) of 10 volts, and the balance gives

$$C_1 = 5.4 \times 10^{-11} \text{ farads}$$

as the C_1 residual. Hence if one per cent. accuracy must be attained, 10^{-10} farad is the lower limit of capacity which can be measured.

A new commutator is now being built, having two segments each 45° long instead of one of 90°. With this will be used brushes set in pairs at 45° instead of 90°. This will cause Q_1 and Q_2 to reach the galvanometer at the same time, and will thus do away entirely with the forced vibrations of the moving system.

It has been found that with certain modifications, this apparatus may be used to measure the insulation resistance of samples as well as their capacity. It seems probable also that the effects of dielectric polarization and absorption on both resistance and capacity may at least be estimated, if not measured quantitatively. This work is now in progress, and the results will be embodied in a later paper.

Metal Cutting with the Electric Arc. G. KEARNEY. (*General Electric Review*, vol. xx, No. 11, November, 1917.)—While the possibilities of the electric arc as a cutting instrument have been generally recognized as a sort of a by-product of its principal function as a welding medium, there seems to be a considerable field in which apparatus designed for electrical welding can be successfully exploited primarily for cutting purposes. Some data have been compiled regarding cutting speeds, but there appears to be a lack of specific information as to the actual process.

Some tests have been made with a 30-kilowatt, 60-volt standard arc welding set installed in a small rolling mill. The set has as yet been in operation only a short time, but sufficient work has been done to demonstrate the value of the method. The mill is at present engaged in working up scrap iron and steel into standard shapes. The scrap metal is cut to suitable size and weight before being placed in the furnace for conversion into billets. The electric cutting apparatus was installed for cutting the considerable quantity of scrap which is too large to be handled by shears. This consists chiefly of plates of various sizes and thicknesses, shafting, bars, rails, etc.

In cutting, as in welding, the positive lead of the direct-current generator is connected to the piece to be cut, while the negative lead is connected by means of a suitable holder to a carbon electrode. A contact is made between this carbon and the work, and in breaking this an arc is formed which almost instantly melts the metal where it strikes. The molten metal is allowed to run off and the arc moves slowly along the work, forming a well-defined cut. No great skill is required in the manipulation of the arc, as when once formed it is fairly stable, and with a properly shaped electrode it can be controlled with a considerable degree of accuracy. A particularly attractive field for this apparatus is in cutting steel plates where accuracy or a sharply defined edge is not essential. For cutting a $^9/_{16}$ plate, the cost of cutting was found to be 6½ cents per foot, including all charges. The actual average speed of cutting was 2.78 minutes per foot, and the total time per foot was 4.07 minutes.

A word of caution is necessary to those unfamiliar with the physiological effects of the electric arc. Great care should be exercised by the operator to avoid accidentally striking the arc without having the face and eyes protected by a mask or shield, and the hands and arms protected by heavy clothing, or preferably by leather. Exposure of the skin to the rays of the arc results in painful burning similar to a severe sunburn, and the rays from the arc cause a very painful inflammation of the eyes.

THE FRANKLIN INSTITUTE.

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Clark, Walton, Jr., Capt.	Field Artillery	
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Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R I

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Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
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Parrish, T. R., Captain	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York

Name and rank	Branch of service	Location
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Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
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Vogleson, J. A., Major		Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
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Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

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Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
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Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
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Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lenher, Victor, Major	Chemical Service Section, N. A.	Washington
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
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Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York

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Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member of Council of National Defense	Philadelphia
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

NECROLOGY.

William Houston Greene, A.M., M.D. The news of the sudden death of Dr. William H. Greene at his summer home in Wenonah, N. J., on August 8th came as a shock to his many friends in Philadelphia and elsewhere. Aged 64 years he looked back on a long and successful career as an educator, chemist and business man, and for many years he had played a prominent part in the scientific, artistic and financial life of our city. His membership in the Franklin Institute dated from August 2, 1884, and it was during the first decade of it that he took an active interest in the affairs of the Institute. During the years 1887–1889 he was a member of the Committee on Science and the Arts, from 1891 to 1892 Vice President and in 1893 President of the Chemical Section. He contributed a number of papers on chemical subjects to the Journal of the Institute, and the library is indebted to him for numerous and valuable gifts.

Doctor Greene was born at Columbia, Pa., on December 30, 1853. When he was a boy his parents moved to Philadelphia, and it was here that he received the greater part of his education. After completing the grammar school course he entered the Boys' Central High School, from which he graduated in June, 1870. Among the members of his class quite a number subsequently attained distinction in various professions, and two of these, Dr. Elihu Thomson and Prof. Henry Willis, were to become his most intimate and life-long friends. Shortly afterwards he matriculated in the Jefferson Medical College, where his pronounced scientific bent led him to specialize in chemistry, and after receiving the degree of Doctor of Medicine from this institution in 1873 he was appointed assistant to B. Howard Rand, who held the chair of chemistry at that time. Two years later he was advanced to the position of Demonstrator of Chemistry.

While there is no doubt that Dr. Greene's work in this position met all requirements, he seems to have felt certain gaps in his training as a chemist, particularly in the field of organic chemistry. So he decided to go abroad and, attracted by the great fame of Adolphe Wurtz, he went to Paris in 1877 and there spent two years in fruitful experimentation and research under the direction of the great teacher, and in close companionship with distinguished chemists like Friedel, Le Bel and Henninger. After his return to this city he became Demonstrator of Chemistry in the Medical School of the University of Pennsylvania, and a year later was elected Professor of Chemistry in the Central High School, which position he held until 1892. It was in this period of twelve years that Dr. Greene achieved his greatest successes as a chemist and teacher. Esteemed and beloved by his students and his associates in the Faculty, he originated and developed methods of instruction that proved most successful, especially along the lines of lecture demonstration and laboratory practice. The Central High School was among the first, if not actually the first, of our secondary schools in which regular laboratory exercises by the students were a part of the instruction in chemistry. It may be admitted that the work of Dr. Greene in this direction was preceded by that of his friend, Elihu Thomson, in the same school, but it was he who first equipped a laboratory with desks, water and gas supply, reagents, etc., for the individual student, and devised a complete course of experiments. During these years also Dr Greene conducted a considerable number of original researches of which the appended bibliography[1] will show the scope. Among the most important of these his work with Dr. William H. Wahl on the reduction of manganese, and that with Dr. Samuel C. Hooker on lapachic acid and its numerous derivatives may be mentioned. A large collection of fine and rare specimens of organic compounds made by Dr. Greene and now in the possession of the Central High School bears witness to the skill and the industry with which he devoted himself to synthetic chemical work. His masterly translation of Wurtz's Elementary Lessons in Modern Chemistry and his own excellent text-book Lessons in Chemistry have both passed through many editions, of which the more recent were edited and revised by H. F. Keller.

As a consulting chemist Dr. Greene long enjoyed an enviable reputation, his experience extending over a wide range of subjects in medical and industrial chemistry.

In 1892 he resigned his professorship to associate himself with his father, the late Stephen Greene, in the printing business. Since then, and

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[1] The writer is indebted for this bibliography to Mr. Alfred Rigling, Librarian of the Institute.

WILLIAM HOUSTON GREENE
From the painting by Frank B. A. Linton

particularly since his father's death in 1908, he devoted himself to the extension of the great printing plant, while he also gave liberally of his time and means to the advancement of the musical and artistic life of Philadelphia. That he still retained a vivid interest in the progress of science is well known to his surviving friends, as well as to many a young and struggling inventor who, through his encouragement and financial aid, has been enabled to develop and make a success of some practical application of a scientific principle.

Among the learned societies of which Dr. Greene was a member are the American Philosophical Society, the Chemical Societies of London, Paris and Berlin, the American Association for the Advancement of Science, the Philadelphia County Medical Society, and many others. At the time of his death he was President of the Philadelphia Musical Art Club.

Dr. Greene was a man of sterling character. Outspoken in his opinions he had a profound contempt for all sham and affectation. Among his most pronounced traits were his sociable disposition and his generosity. His contributions to various charities and his gifts to individuals whom he believed to be in need were innumerable, yet he hardly ever spoke of them even to his intimate friends. Among the bequests he made to institutions of learning were those of his unique and most valuable chemical library to Jefferson College, of $2000 to the American Philosophical Society for its publication fund, and of a large part of his chemical apparatus and collection to the Central High School. On the largest scale his beneficence was exemplified by the bountiful contributions he made to the American Red Cross, the Belgian Relief Committee, and indeed to every war charity that appealed to his warm and loyal heart.

HARRY F. KELLER.

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BOOK NOTICES

CHIMIE ET INDUSTRIE. Under this title, the newly-formed French Society of Industrial Chemistry, that has begun very auspiciously, will publish a monthly journal, the first number of which, dated June, 1918, has just arrived. It is about the form and size of the Journal of Industrial and Engineering Chemistry, is well printed on good paper, includes 156 pages and many illustrations. The original matter covers 84 pages, after which are about forty pages of abstracts of general chemical literature, and of patents. An interesting feature is the inclusion of a number of essays of a philosophic tone, relating to the economic issues at present and that may arise after the war. This section is termed "Organization economique." The number closes with two pages of book reviews.

The copy in hand contains no advertisements, a special notice being printed on the back of the title-page to the effect that an order of the French Government forbids advertisements in copies intended for transmission to other countries.

From the numerous chemical formulas we get the gratifying information that French chemists have at last adopted N instead of Az as a symbol, but unfortunately they still continue to write the exponents as superiors. Let us hope that in this particular also they will soon be able to say "Nous avons changé tout cela."

HENRY LEFFMANN.

EDIBLE OILS AND FATS. By C. Ainsworth Mitchell, B.A., F.I.C. London, Longmans, Green and Company, 1918. 123 pages, contents, bibliography, and index, illustrations. 8vo. Price, $2.00 net.

This is one of the series of monographs on industrial chemistry, to be written by specialists, under the editorial supervision of Sir Edward Thorpe, C.B., LL.D., F.R.S. Mr. Mitchell is so well known as an industrious and competent worker in the field to which the book is devoted that we are assured that it will be satisfactory. The field is, however, one that has been extensively studied and extensively discussed in the literature of chemistry of recent years, so that little new can be expected. The work includes concise statements of the composition and properties of the edible fats and oils, methods of extracting them from the raw materials and purifying and preparing them for the market. Many analytic data are also given.

Among the items of special interest is the description of some of the standard methods of manufacturing commercial butter-substitutes. An extensive bibliography is appended.

It is interesting to note that while France, Italy and the United States have adopted officially the glycerol-soda method for determining the volatile acids in butter-fat and its substitutes, English practice still adheres to the old alcohol-soda procedure. We cannot, of course, expect simplified spelling of chemical terms in an English book, but there seems to be no reason why the term "glycerol" should not be used, nor why the older term if used should be spelled "glycerin" on page 46 and "glycerine" on page 103. The difficulties that arise in consequence of differing terminology in the two English-speaking nations are often in evidence, for example, "peanut," "earthnut" and "groundnut" are not found in the index; for information concerning them one must look for "arachis."

HENRY LEFFMANN.

NOTIONS FONDAMENTALES DE CHIMIE ORGANIQUE. Par Chas. Moureu. Paris, Gauthier-Villars, 1918. Fifth edition, 548 pages, 8vo.

The fourth edition of Prof. Moureu's book was reviewed in this journal three years ago. The text makes no pretensions to being a laboratory manual. The author confines himself entirely to his chosen task of presenting the theory of the subject, and omits all experimental directions. The logic of this position is evident. The student is sure to have a manual at hand. Even if he had not, the attempt to follow the brief recommendations in his text-book could result only in disaster.

Although the general plan of treatment remains unaltered, the fifth edition is somewhat larger than the fourth. The additional space has been devoted to a more extended treatment of stereochemistry, and of the relations between chemical constitution and physical properties. A brief but excellent chapter upon dye-stuffs has been added.

A careful reading of the fifth edition has confirmed the reviewer in his opinion that this is the best text-book of organic chemistry that has yet seen the light. It is almost the only one that can be read through as a whole with interest and pleasure. The fact that five editions have been called for in fifteen years is evidence of the wide recognition of its merits in France and the neighboring countries. It is unfortunate that no English translation exists for the use of students in Great Britain and the United States. Such a translation would facilitate to a marked degree the study of a subject of considerable difficulty, and of great and growing importance.

ROBERT H. BRADBURY.

VAN NOSTRAND'S CHEMICAL ANNUAL, Fourth Issue. Edited by John C. Olsen, A.M., Ph.D.; assistant editor, Maximilian P. Matthias, Ch.E. New York, D. Van Nostrand Company, 1918, XVIII + 778 pages. 12mo. Price, $3.00 net.

Four years have elapsed since the appearance of the third issue of this handbook. In the present edition, the molecular weights and factors have been recalculated to correspond to the international atomic weights for 1917.

New tables have been added concerning properties of the elements; calibration and true volume of glass vessels; use of indicators; properties of oils, alloys, glass, etc.; specific gravity; vapor pressure; units of weights and measures; capacity of tanks; conversion of units of heat, electricity, temperature, etc.; freezing point mixtures. Other tables have been revised in accordance with recently published data. The frontispiece is a portrait of Ira Remsen.

JOSEPH S. HEPBURN.

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Your Business and War Business: A handbook on industrial adjustments by Harold G. Moulton. 23 pages, 8vo. Chicago, Union League Club, 1918.

The Peat Industry. C. C. OSBON. (*U. S. Geological Survey*).—The peat industry in the United States was prosperous in 1917, for the quantity of peat sold exceeded that in any preceding year. The peat sold in 1917 amounted to 97,363 short tons, a quantity greater by 44,857 tons, or about 85 per cent., than that sold in 1916, and by 42,220 tons, or nearly 77 per cent., than the record annual sales, 55,143 tons, established in 1911.

The average price received for peat in 1917 at the point of consumption was a little more than $7.29 a ton, and the gross market value of the output was $709,900, a gain over 1916 of 26 cents in average price per ton, and of $340,796, or about 92 per cent., in market value.

The total number of plants producing peat in the United States in 1917 was 18, an increase of 5 over 1916. All the producers operating in 1916 except two contributed to the output in 1917, and seven companies that were not represented in that year reported commercial production. Many new companies were organized in 1917 that did not complete their plants in time to contribute to the year's output. The plants known to be at work in 1917 were distributed as follows: California, 2; Florida, 2; Illinois, 2; Indiana, 1; Massachusetts, 1; New Jersey, 5; New York, 3; Pennsylvania, 1; and Virginia, 1.

All the producers reported that the demand for peat exceeded the supply, and some stated that, on account of railroad embargoes and the scarcity of labor, they were unable to meet the demands of their regular customers. Improvements designed to increase production in 1918 were made to substantially all the peat plants operated in 1917.

CURRENT TOPICS.

The Duty of the Employer in the Reconstruction of the Crippled Soldier. DOUGLAS C. MCMURTRIE, Director, Red Cross Institute for Crippled and Disabled Men, New York City.—Soon after the outbreak of present hostilities the European countries began the establishment of vocational training schools for the rehabilitation of disabled soldiers. They had both the humanitarian aim of restoring crippled men to the greatest possible degree and the economic aim of sparing the community the burden of unproductivity on the part of thousands of its best citizens. The movement had its inception with Mayor Édouard Herriot of the city of Lyons, France, who found it difficult to reconcile the desperate need for labor in the factories and munition works while men who had lost an arm or a leg but were otherwise strong and well were idling their time in the public squares. He therefore induced the municipal council to open an industrial school for war cripples which has proved the example and inspiration for hundreds of similar schools since founded throughout France, Italy, Germany, Great Britain, and Canada.

The disability of some crippled soldiers is no bar to returning to their former trade, but the injuries of many disqualify them from pursuing again their past occupation. The schools of training prepare these men for some work in which their physical handicap will not materially interfere with their production.

The education of the adult is made up largely of his working experience. The groundwork of training in his past occupation must under no circumstances be abandoned. The new trade must be related to the former one or be, perhaps, an extension or specialization of it. For example, a man who had done manual work in the building trades may by instruction in architectural drafting and the interpretation of plans be fitted for a foreman's job, in which the lack of an arm would not prove of serious handicap. A trainman who had lost a leg might wisely be prepared as a telegrapher, so that he could go back to railroad work, with the practice of which he is already familiar. Whatever training is given must be thorough, for an adult cannot be sent out to employment on the same basis as a boy apprentice. He must be adequately prepared for the work he is to undertake.

The one-armed soldier is equipped with working appliances which have supplanted the old familiar artificial limb. The new appliances are designed with a practical aim only in view; they vary according to the trade in which the individual is to engage. For example, the appliance for a machinist would be quite different from that with which a wood turner would be provided. Some appliances have attached to the stump a chuck in which various tools or hooks can interchangeably be held. The wearer uses these devices only while at work; for evenings and holidays he is provided with a " dress arm " which is made in imitation of the lost natural member.

An important factor in the success of re-educational work is an early start, so that the disabled man shall have no chance to go out unemployed into the community. In even a short period of exposure to the sentimental sympathy of family and friends, his " will to work " is so broken down that it becomes difficult again to restore him to a stand of independence and ambition. For this reason, therefore, the plan for his future is made at as early a date as his physical condition admits, and training is actually under way before the patient is out of the hospital.

In the readjustment of the crippled soldier to civilian life, his placement in employment is a matter of the greatest moment. In this field the employer has a very definite responsibility. But the employer's duty is not entirely obvious. It is, on the contrary, almost diametrically opposite to what one might superficially infer it to be. The duty is not to " take care of," from patriotic motives, a given number of disabled men, finding for them any odd jobs which are available, and putting the ex-soldiers in them without much regard to whether they can earn the wages paid or not.

Twelve men sent to twelve jobs may all be seriously misplaced, while the same twelve placed with thought and wisdom and differently assigned to the same twelve jobs may be ideally located. If normal workers require expert and careful placement, crippled candidates for employment require it even more.

The positive aspect of the employer's duty is to find for the disabled man a constructive job which he can hold on the basis of competency alone. In such a job he can be self-respecting, be happy, and look forward to a future. This is the definite patriotic duty. It is not so easy of execution as telling a superintendent to take care of four men, but there is infinitely more satisfaction to the employer in the results, and infinitely greater advantage to the employee; and it is entirely practical, even in dealing with seriously disabled men. With thoughtful placement effort, many men can be employed directly on the basis of their past experience. With the disabled soldiers who profit by the training facilities the government will provide, the task should be even easier. This, then, constitutes the charge of patriotic duty upon the employer: To study the jobs under his jurisdiction to determine what ones might be satisfactorily held by cripples; to give the cripples preference for these jobs; to consider thoughtfully the applications of disabled men for employment, bearing in mind the importance of utilizing to as great an extent as possible labor which would otherwise be unproductive; to do the returned soldier the honor of offering him real employment, rather than proffering him the ignominy of a charity job.

Increasing the Yield of Sugar Cane. ANON. (*The Journal of Industrial and Engineering Chemistry*, vol. 10, No. 5, p. 407, May, 1918.)—According to the *Little Journal* for April, Mr. C. F. Eckart, a leading authority on sugar planting in Hawaii, has developed a process in the raising of sugar cane in Hawaii which reduces the cost of labor 50 to 70 per cent. and increases the yield 28 per cent. His process consists in laying yard-wide strips of paper longitudinally over the rows, holding them in place by covering the edges with cane-field trash. The paper must be strong enough to keep down the weeds, but not strong enough to kill the young cane. Five or six weeks after applying the paper the weed seeds that can germinate have done so and their sprouts are smothered, while the shoots of the sugar cane, being stiff and sharp, have either come through the paper or show their presence by little tent-like elevations in the paper, which can be split with long knives by laborers passing between the rows.

An attractive problem in industrial research was presented to the Arthur D. Little, Inc., laboratories when the question of making paper from bagasse suitable for this purpose was put to them. Many sorts of paper have been made from bagasse, but they have tended to be hard and tinny, whereas there was required here a paper which would be strong enough to withstand the Hawaiian rainfall and yet give way under constant gentle pressure. Also, it had to be dark in color and unusually cheap. This problem has been solved and plans are being made for a paper mill to take care of Mr. Eckart's plantation. Some interesting pictures appear in the *Little Journal*, comparing cane four and one-half months after planting, one showing cane which has received the Eckhart treatment, another which was cultivated and hoed in the usual manner.

Making Foundations with a Pile Driver. ANON. (*Scientific American*, vol. 118, No. 16, p. 357, April 20, 1918.)—A unique method of building foundations which has found extended use in France and Belgium has been developed by the engineer Louis Dulac. This method consists, in its most general terms, in consolidating the ground by blows from a weight without removing any material whatever. The resulting holes are then filled with stones or some aggregated material, likewise under pressure; and by making borings sufficiently close there are thus obtained a series of subterranean columns well fixed in the earth.

To bore the holes and pack them mechanically a modified pile driver is used. Three hammer heads are provided. The perforating hammer is conical, weighs approximately two and a half tons, and is about 33 inches in diameter. This has a point of high-grade steel. A packing hammer of cast iron, ogival in shape, is three or four inches smaller than the borer. The finishing hammer is in the form of a truncated cone. Unlike the two others which work with the point down, this is used with its smaller base upward. When the hole made by the first head is sufficiently deep, judged by the gradual diminution of the distance which the head penerates with each blow, tamping is proceeded with, giving the desired vertical and lateral compression of the earth and providing a base for the column. For this there is thrown into the hole a concrete mixture. Under the blows of the tamping hammer the mass gradually forces the bottom of the hole out flatter; but the resistance offered by the already partly compacted earth is sufficient to spread the cement plug out sideways. The result is a solid block in the bottom of the hole. This is filled with any appropriate concrete mixture.

The Present Economic and Social Conditions as Results of Applied Science and Invention. G. W. PERKINS. (*The Scientific Monthly,* vol. 6, No. 3, p. 223, March, 1918).—During the last quarter of a century men of science have been so engrossed in the fascinating problems on which they have been working that they have taken little or no time to inform the public as to the practical effect that modern scientific inventions were bound to have on every-day life. These inventions have been placed in the hands of the people of the world within the last third of a century, and their application to business and social affairs has overthrown and carried away a countless number of old practices and precedents.

As man-made laws are the outgrowth of centuries of effort, it did not seem possible that anything would come into the world that would set all this cumulative knowledge and experience to naught almost overnight. Such, however, is the actual situation; but a vast majority do not realize this—do not at all understand it. It is also true that a large number of the more intelligent class have refused to accept the new conditions in which we live and have insisted on continuing under the old system, following old precedents and practices. As a result, a mighty conflict has engaged us and will continue to engage us until people realize that a mighty upheaval has taken place; that we have entered a new world of thought and action, dominated almost wholly by the discoveries of science within the last half century; that new codes of business morals, of finance, of industry are being set up; and that it behooves us all to give the best thought, the broadest vision, the most unselfish devotion to the erection of a new structure that will be in harmony with modern economic needs.

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A PHYSICAL STUDY OF THE WELSBACH MANTLE.*

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I. INTRODUCTION.

THE physical theory of the ordinary incandescent mantle, composed of thoria and ceria (Auer or Welsbach mantle), has been most fully treated by Rubens.[1] He found the high efficiency of the approximately 99 per cent. thoria, 1 per cent. ceria mixture to be due to two causes: First, to the low emissive power of the thoria, in virtue of which it attains a high temperature in the flame; second, to the introduction of a rather sharp absorption (emission) band in the visible spectrum by the small quantity of ceria (when hot). The addition of more ceria broadens the emission band, thereby contributing proportionately more infra-red energy, increasing the total radiation, and lowering the temperature, so that the radiant luminous efficiency falls off again after

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* Based on a lecture delivered by Doctor Ives at a meeting of the Section of Physics and Chemistry held Thursday, January 10, 1918.

Contributed by the Research Laboratories of the Welsbach Company, Gloucester City, New Jersey.

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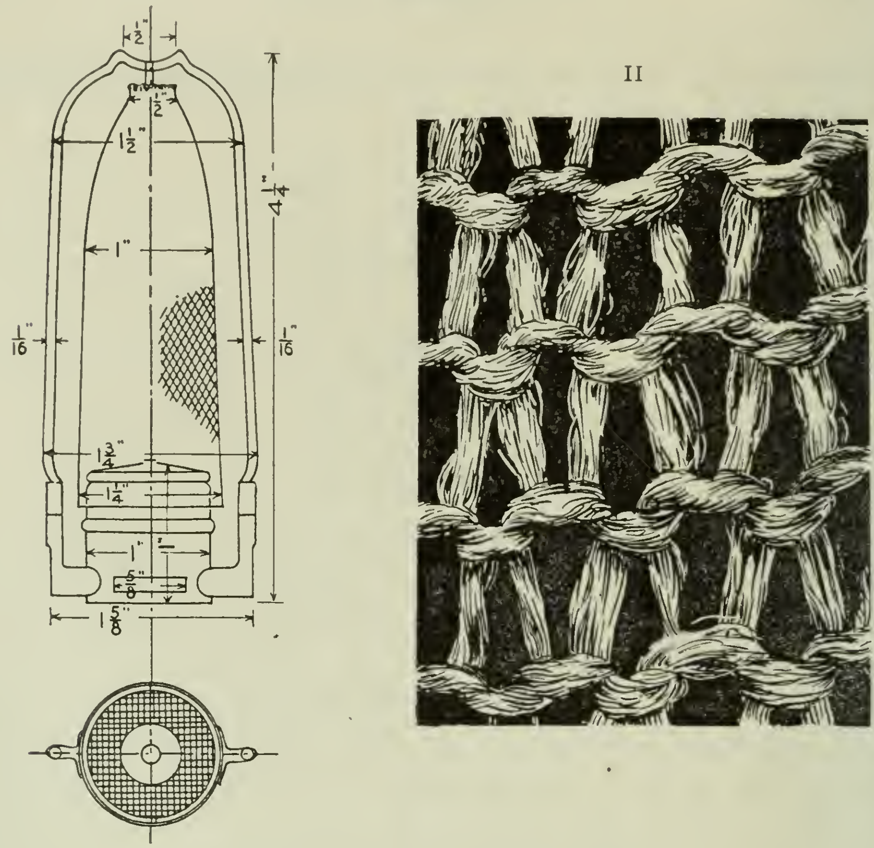
passing through an optimum. For the details of this theory, and of the general theory of temperature radiation, on which it is based, reference should be made to Rubens's [1] original paper, and to modern text-books on heat radiation.[2]

The object of the present study was to fill out some details of the theory of the ordinary mantle, and to apply the methods of study used by Rubens, as well as certain other new methods, to mantles composed of other oxides and oxide mixtures. The broad aim was to improve our knowledge of the behavior of the incandescent gas mantle, in the hope that information of value in its manufacture and development would be obtained.

Fig. 1.



I. Dimension drawing of mantle and burner.
II. Photomicrograph of (silk) mantle structure.

II. SOURCE AND CHARACTER OF THE MANTLES STUDIED.

The mantles for the work with gas heating were uniformly of the upright type, of the dimensions and shape shown in Fig. 1 (I). They were made under direction of Mr. S. Gulbrandsen by

Mr. J. G. Buckley, of the Welsbach Company, of cotton or silk fibre, as noted, and burnt off in a hardening flame, according to the regular factory procedure. The weave was uniformly of the chain-stitch variety, shown in the photomicrographs of the silk.

The weight of oxide (ash) per unit area, the relative percentages, by weight, of oxides in mixtures, the character of the weave, are all factors which have influence on the light given by the mantle. For a complete study, the best weight and character of weave, having regard to physical strength and deterioration during burning, should be determined by experiment for each oxide or mixture. In a survey of a large number of materials, such as that made here, a detailed study of each mantle could not be undertaken. Each was therefore made up of a weight and structure found practicable by rough experiment, and careful record was kept of these details. Separate experiments on the effect of varying the weight of ash per unit area made on a representative mantle and recorded below showed the limits of possible change of characteristics due to this factor. In general, any changes by weight within probable or practical limits would have been of comparatively small significance compared with the differences due to different composition.

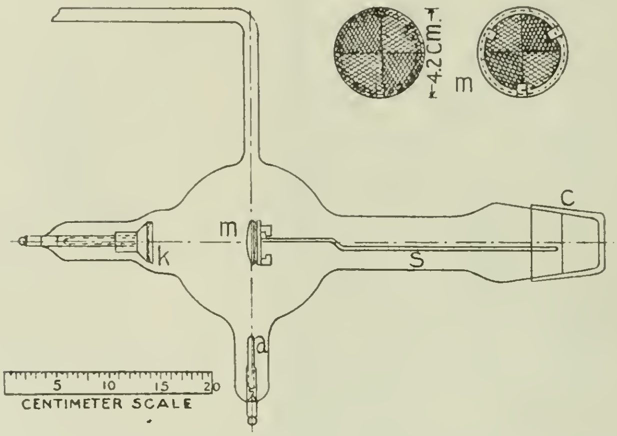
Special mantles were made up in flat disk form for experiments in heating by the cathode discharge in a vacuum tube, and special small mantles for heating with the hydrogen-chlorine flame. These are described in connection with the experiments made with them.

III. METHOD OF HEATING.

For the majority of the tests the mantles were heated in the usual manner by contact with the non-luminous Bunsen flame. The gas used was a representative (Philadelphia Gas Works) mixed coal and water gas, of approximate proportions 20 per cent. coal and 80 per cent. water, and average heating value of 660 B.t.u. per cubic foot, supplied at a uniform pressure of 3 inches. Throughout the work all measurements were made on the mantles without the usual glass chimney, which, although increasing the mantle efficiency, would have interfered with some of the more important tests. The question of burner adjustment proved to be one of great importance. Ordinarily the mixture of gas and air was chosen which would give the maximum luminosity. It was found, however, that with some mantles a very marked difference of behavior appeared, depending on whether the mantle was entirely outside or entirely inside the flame. For instance, with ceria two extreme adjustments are possible—one of maximum luminosity and temperature, in the outside, oxidizing flame, the other of minimum luminosity and temperature but of maximum total radiation. As a consequence of these observations measurements were made on some mantles with several adjustments.

A further development of this line of study consisted in heating pieces of mantle in the space between the outer and inner cone of the burner, or on the inside of a Meker burner flame, and withdrawing the material through a side tube. The results of this procedure will be treated under the descriptions of the various mantles.

Fig. 2.



Special vacuum tube for heating mantle materials by cathode ray bombardment: *m*. Disk mantle. *c*. Removable ground cap. *k*. Cathode. *a*. Anode. *s*. Glass rod frame for holding mantle.

In one case (thoria-ceria) heating of small mantles with a hydrogen flame burning in chlorine was tried, the hydrogen flame being ignited in air under a bell jar, and the air then being displaced by chlorine.

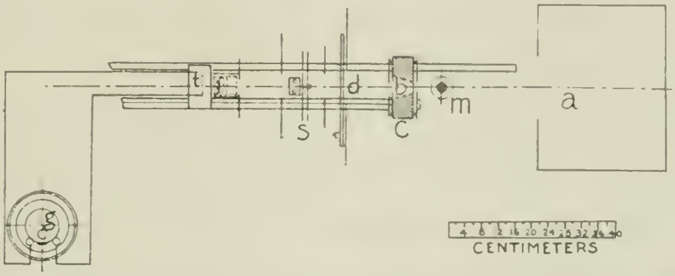
Experiments were made on some mantles and mantle mixtures by heating by cathode rays in a vacuum tube. The tube used is shown, drawn to scale, in Fig. 2. Its special feature is the removable ground cap (*c*) whose use permits the removal of the special disk mantle (*m*) and the introduction of another. The tube must, of course, be re-exhausted for each mantle, which was done by a Gaede mercury pump. The high voltage necessary for the discharge was supplied either by a large induction coil or by a 20,000-volt transformer operated on a 220-volt, 60-cycle power circuit.

IV. METHODS OF STUDYING RADIATING CHARACTERISTICS.

1. *Measurement of Total Radiation.*

In order to determine the efficiency of any radiator as a transformer of the energy applied to it into radiant energy, and to determine its emissive power or radiating capacity as compared to a full radiator (black body), it is necessary to measure the radiant energy.

Fig. 3.



Plan of apparatus for measuring radiance and radiant luminous efficiency of mantles: *a*. Black background. *b*. Bright tin sheet with 1 cm. diameter aperture. *c*. Metal block support for tin sheet *b*. *d*. Double-walled tin shutter. *f*. Spectral luminosity curve filter. *s*. Sector disk. *t*. Thermopile. *g*. Galvanometer.

This was done on the mantles by means of a surface thermopile of 72 Bi-Ag elements (Coblentz design), in conjunction with a sensitive d'Arsonval galvanometer (Leeds & Northrup construction, sensibility 33 mm. per microvolt at terminals, resistance 12.5 ohms, period 7 seconds). The thermopile-galvanometer system was calibrated by means of a standard of radiant intensity, in the form of an incandescent electric lamp, obtained from the Bureau of Standards. The primary object of the study being the mantle itself, rather than the burner, mantle supports, etc., the radiation was measured from a definite area of the mantle, about one-third up from the bottom, as limited by a circular aperture of one centimetre diameter. A diagram of the apparatus is shown in Fig. 3. Special features are the background (*a*), consisting of a deep black enclosure or hole, and the screen of bright tin (b), in which is cut the 1 cm. diameter circular aperture, supported by the large block of metal (c), which serves by its large heat capacity to prevent the screen about the aperture from being heated up by proximity to the mantle (m). A double-walled sheet tin shutter (d) and a very complete system of screens (not all shown in the diagram) are additional special features. The whole apparatus is set up in a thick-walled basement room, where the temperature holds fairly constant.

A complete measurement of the radiant energy falling upon the thermopile involves in general an observation of the galvanometer deflection due to the background, and of the deflection due to the metal aperture and block (c). The latter, because of the large mass of the metal, was negligible, the former usually so. No change in the calibration of the system was detected over a long period.

The actual quantity given by a measurement is the watts received by the thermopile, at a given distance, from a certain area of mantle. This is immediately reducible to watts emitted per square centimetre of mantle, in a given direction, per unit solid angle. This is the specific radiant intensity or *radiance,*[3] a quantity of exactly the same significance in radiation as is brightness in illumination. Its integral throughout the whole sphere and over the whole radiating surface give the total radiant emission. Inasmuch as the measurements here made are in one direction only, and from only one part of the mantle, the total radiant emission is not directly derivable from these measurements. The emissive power, or ratio of the radiant emission to that of a black body, at the same temperature, is directly obtained by comparing the quantity measured (radiance) with the similar quantity for the black body, which can be calculated from the black body laws by means of the experimentally established constants.

2. *Measurement of the Radiant Luminous Efficiency.*

The radiant luminous efficiency,[4] or luminous efficiency of the radiated energy, is defined as the ratio of the radiant energy, transmitted through a filter whose transmission at each wavelength is proportional to the luminosity of the equal-energy spectrum (maximum of luminosity being called unity) to the total radiant energy. It informs us upon the characteristics of the mantle (and flame) as a light-source, irrespective of the losses due to the method of heating; *i.e.*, conduction and convection of energy away by the mantle supports, products of combustion, and surrounding atmosphere.

The instrument for its measurement is the radiometer described in the previous section, to which is added a spectral luminosity curve filter (*f*), composed of a solution of certain inorganic salts in water, which had been previously worked out, whose transmission through the spectrum accurately copies the luminosity curve of the spectrum for the normal eye. Measurements of the radiation passing through this screen are directly proportional to the luminous intensity of the radiation.

The complete determination of radiant luminous efficiency consists of two measurements: one, that of the radiant energy, without the interposition of the special filter (in practice cut down to measurable value by the sector disks); the other, that of the radiant energy transmitted by the screen (making proper correction for the maximum transmission, which should be 100 per cent., but is always less in any actual practical filter—in this case 57 per cent.). The ratio of the latter to the former is the desired efficiency. Details of the apparatus and its use have been given in a previous publication.[5]

Measurements of this factor were made upon the *whole* mantle, as exposed by an aperture obstructing merely the burner and burner supports. This inclusion of the whole mantle was made practically imperative because of the small amount of energy received through the luminosity curve filter when the mantle area was restricted to the small spot of maximum luminosity on which most of the other measurements were made. Because of the falling off in temperature toward the top of the upright mantle the efficiency measured for the whole mantle is considerably less than it would be if the mantle were uniform. The comparison frequently made below, between the efficiency of the mantle and that of a black body at the same temperature, is for this reason subject to considerable qualification. It is introduced largely to bring out the selective characteristic of the mantle radiation, which is, for the reason given, even greater than the data indicate as exhibited.

3. *Measurement of Total Luminous Efficiency and Radiational Efficiency.*

The total luminous efficiency is the ratio of the luminous energy yielded (energy passed through a luminosity curve filter) to the total energy supplied to the light-source. The luminous energy is measured in the manner described in the last section; the total is derived from the heating value and rate of consumption of the gas. Both must, of course, be reduced to the same unit (*e.g.*, watts). When this is done the efficiency is expressible as a simple fraction or percentage, the unit of which is the most efficient light possible.

An alternative method of arriving at this figure is at hand when the total efficiency has been determined in lumens per watt or lumens per British thermal unit per hour. In this case it is only necessary to multiply the efficiency so expressed by the mechanical equivalent of light, which is 0.00159 watts per lumen, or 0.00543 B.t.u. per hour per lumen.

Since this total luminous efficiency is arrived at by taking into account all the convection and conduction losses, and the radiant luminous efficiency disregards these, it is possible, from the two measurements, to arrive at the *radiational efficiency* or efficiency of transformation of the applied energy into radiant energy. If we symbolize the rate of consumption of energy (power) by P, the rate of radiating energy by R, and the rate of radiating luminous energy by L, we have that the

$$\text{Total luminous efficiency} = \frac{L}{P}$$

$$\text{Radiant luminous efficiency} = \frac{L}{R}$$

$$\text{Radiation efficiency} = \frac{R}{P} = \frac{\frac{L}{P}}{\frac{L}{R}}$$

or the radiational efficiency is the quotient of the total luminous by the radiant luminous efficiency.

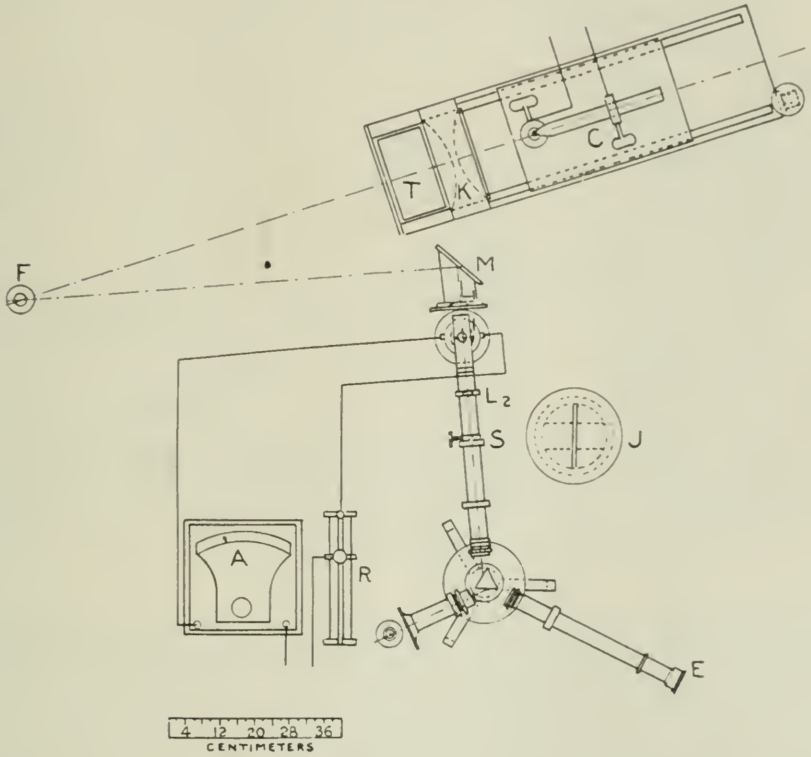
This method of obtaining the radiational efficiency assumes that the radiant luminous efficiency is the same in all directions from the source as in the direction measured, which is not in general accurately the case, although nearly enough so to get at a fair approximation. Other methods of arriving at the radiational efficiency will be treated below.

4. *Measurement of Spectral Distribution of Emission.*

(*a*) VISIBLE SPECTRUM.

The emission through the visible spectrum was measured by means of a spectro-pyrometer of the Hennings type, shown diagrammatically in Fig. 4. An image of the mantle or other surface to be measured (*F*) is formed by the mirror *M* and lens L_1, in the plane of the carbon incandescent lamp *I*, and an image of this image and of the horizontal portion of the lamp filament is focused by the lens L_2 on the slit *S* of a small spectrometer. On observing the spectrum of the mantle at *E*, the eye-piece, it is seen crossed by a narrow band corresponding to the carbon filament. If a current is sent through the filament, its brightness may be varied until its matches that of the spectrum at any one color. The region of the spectrum to be used is limited to a narrow strip by an appropriate slit inserted in the plane of the eye-piece,

FIG. 4.



Spectropyrometer: *F*. Mantle. *M*. Mirror. L_1. Lens. *I*. Carbon incandescent lamp. L_2. Lens. *S*. Slit. *E*. Eye-piece. *J*. Appearance of spectrometer field. *A*. Ammeter. *R*. Rheostat. *C*. Carbon arc lamp. *K*. Lens. *T*. Water tank.

as shown in the enlarged insert *I*. The wave-lengths are read off the scale provided with the instrument.

In order to interpret the settings, which are in terms of current through the carbon lamp filament, the entire apparatus must be calibrated on a "black body." This was done by the aid of a Northrup resistance furnace. The spectro-pyrometer was, for this purpose, so placed that the mirror *M*, on turning through 90 degrees, was exactly over the top aperture of the furnace. Settings of lamp current were then made through the spectrum for a range of temperatures as measured optically by a carefully calibrated Wanner pyrometer, from 1100° to 2000° Kelvin. Unless the carbon lamp filament is absolutely black the black-body temperature lamp-current curves should differ for the different parts of the spectrum. Actually it was found that to within the limits of experimental error the same calibration curve held throughout the region 0.45μ–0.7μ.

By the use of this calibration, current settings are immediately reduced to black-body temperatures, and these in turn are reducible by the black-body equation (Wien) to watts per square centimetre (of radiating surface) per unit solid angle, per micron wave-length interval (0.0001 cm.), the unit employed throughout in plotting the results both for visible and infra-red radiation.

The constants used in calculating the working data sheets were

$$C_1 = 3.73 \times 10^4 \qquad C_2 = 14390$$

These measurements of visible emission were all made on the edge of the mantle, which presents the appearance of a continuous surface when viewed nearly tangentially. As plotted, the values have been reduced in the proportion of 1 : 1.2, which by photometric test represents the relative brightness of centre and edge. The results are therefore shown in terms of the porous centre, a method of plotting made necessary by the fact that the infra-red measurements had to be made on the centre of the mantle and the ratio of edge to centre radiance (not easy to determine satisfactorily) may differ from the distribution of brightness.

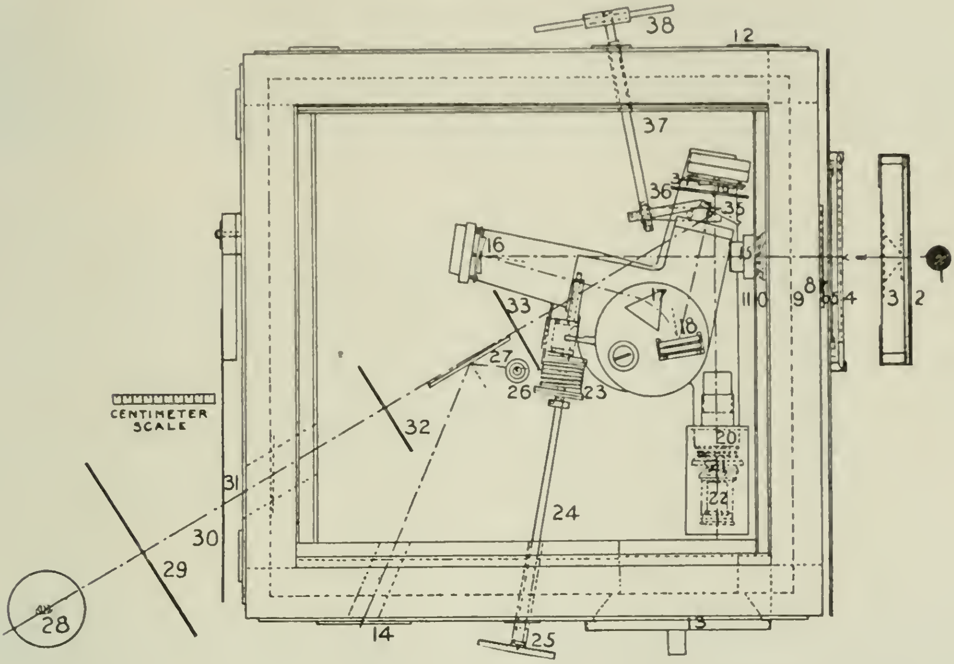
(*b*) INFRA-RED SPECTRUM.

The Spectrometer.

A Hilger infra-red spectrometer was used for the determination of the distribution of radiant energy in the long wave region.

This instrument, which is shown in plan in Fig. 5, is of the constant deviation type generally referred to as the Wadsworth mounting. Its essential parts, in their order along the optical path, are: incident slit, collimating mirror, rock-salt prism, plane mirror, emergent slit, linear thermopile.

FIG. 5.

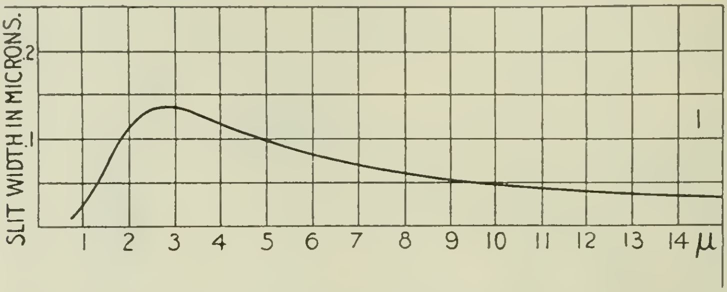


Infra-red spectrometer: 1. Welsbach burner with mantle. 2. Bright tinned sheet iron. 3. Cast iron screen. 4. Double walled shutter. 5. Slide over opening in *C*. 6. Bright sheet iron screen. 7. Lid allowing adjustment of slit. 8. Outer sheet iron wall. 9. Inner sheet iron wall. 10. Space bounded by two sheet iron walls filled with asbestos. 11. Cardboard. 12. Hinge. 13. Door admitting to thermocouple. 14. Window for observing drumhead. 15. Incident slit. 16. Collimating Mirror. 17. Rock salt prism. 18. Plane mirror. 19. Focussing mirror. 20. Emergent slit. 21. Thermocouple. 22. Microscope. 23. Wave-length drum. 24. Extended axis of wave-length drum. 25. Graduated disk for reading wave-lengths beyond 10. 26. Flashlight lamp. 27. Plane mirror. 28. Reference standard of radiation. 29, 32, 33, 34. Screens. 30. Shutter. 31. Window to admit radiation from reference standard. 35. Auxiliary mirror. 36. Supporting axis for mirror. 37. Key with arms, 38, to raise and lower mirror.

The settings and manner of use of some of these parts, as they were used in the present investigation, must be recorded in some detail. Starting with the slits: These were set at 0.5 mm. width throughout the work; their effective length is 10 mm. The value of this slit width in wave-length interval throughout the spectrum is shown in Fig 6. The plane and concave mirrors are of nickel-steel of a non-corroding formula, which, however, acquire a slight white coating on standing that rubs off easily. A knowledge of the reflecting power of these mirrors is, of course, necessary for work of this kind. This was obtained from measurements on a plane mirror of the same material, furnished by the makers, whose reflecting power relative to that of a freshly deposited silver film was measured in the infra-red by the infra-red spectrometer and thermopile; in the visible and ultra-violet, by a quartz spectrometer and photo-electric cell with check measurements on a spectrophotometer. The reflecting power curve thus obtained is shown in Fig. 7.

The rock-salt prism (32 mm. height, 42 mm. face) was furnished by the makers with a protective coating of pyroxylin. This was washed off, and dependence was placed, for the preservation of the prism, on the use of drying material in the spectrometer enclosure. On several occasions some repolishing was necessary. No corrections for absorption in the rock-salt prism were considered necessary.

FIG. 6.



Value of slit width in wave-length units.

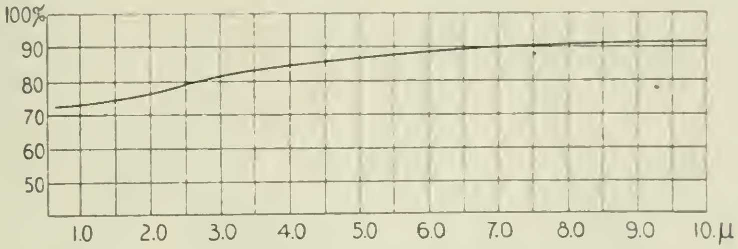
The thermopile is a linear one, Hilger design, consisting of ten bismuth-silver junctions, with a receiving surface 1 mm. by 10 mm., and a resistance of 2.5 ohms. It is mounted upon a bone base and attached immediately behind the emergent slit.

Wave-lengths are read upon the drum calibrated by the maker to 10μ. An extrapolation to 14μ was made upon the scale of the extension head going to the outside of the enclosure, to be presently described. A dispersion curve of the prism, necessary to reduce the deflections in the different parts of the spectrum to correspond to uniform wave-length intervals, was constructed from the maker's calibration of the drum.

For purposes of thermal and moisture insulation the whole spectrometer was placed in a galvanized iron box blackened on the inside, as shown in the plan, Fig. 5. The top and four sides of this box were double-walled doors, and were stuffed with cotton, and extra double walls, 1.2 cm. apart, filled with powdered asbestos, completed the thermal insulation.

In order to maintain the dryness of the interior, calcium chloride and phosphorous pentoxide in open vessels were used. The outside edges of the doors were sealed by strips of electrician's tape, leaving, as the sole opening for direct communication with the atmosphere of the room, the incident slit. This could be adjusted from the outside after the removal of a small lid. It was also possible to close the opening to the slit by means of a small cork when the instrument was not in use.

FIG. 7.



Reflecting power of nickel-steel mirrors of infra-red spectrometer.

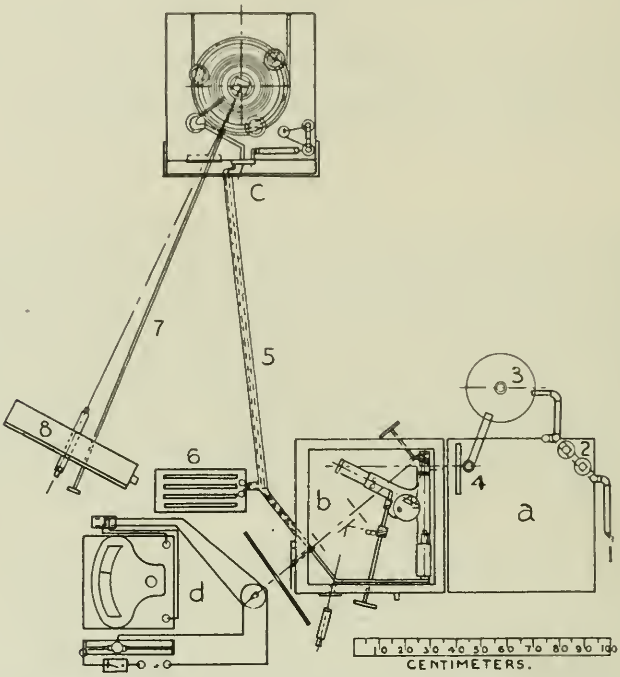
Great care was taken to shield the spectrometer box from direct radiation from the mantle under observation. This was accomplished in part by a sheet of bright-tinned iron placed about a centimetre away from the side of the box facing the radiation source. In addition the aperture (1 cm. diameter, round) which limited the area of the mantle surface observed was mounted on a thick iron plate (1 inch thick by 8 inches diameter), which in turn was protected by a sheet of bright-tinned iron facing the mantle and separated from the iron plate by about 0.6 cm. The shutter used to expose the spectrometer slit was for similar reasons made of double-walled bright tin with a layer of cardboard between.

These precautions taken for thermal insulation secured steadiness under operating conditions, necessary and desirable because of the considerable time involved in carrying out all the measurements.

The use of this large insulating box made the wave-length drum inaccessible and necessitated some auxiliary means for turning it, which was provided by extending the axis through the wall to an outside graduated disk. The drum itself was then read by a reading telescope through a glass window, the extrapolation beyond 10μ was made in terms of the external disk graduation.

An additional window to admit light from an auxiliary standard lamp, for calibrating purposes, and a mirror of ground glass, which could be turned into position, to reflect its radiation to the thermocouple, complete the spectrometer outfit.

FIG. 8.



Plan of infra-red set-up: *a*. Table supporting gas accessories: 1. Pipe leading to source of gas. 2. Pressure regulators. 3. Steadying capacity. 4. Welsbach burner. 5. Leads in sheath from thermocouple to galvanometer. 6. Resistance box. 7. Handle for control magnet. 8. Reading telescope and scale: *b*. Table supporting spectrometer and accessories. *c*. Suspension and support for galvanometer and accessories. *d*. Comparison radiation standard and accessories.

The Galvanometer.

The thermocouple and a resistance box were connected in series to a Thomson galvanometer, shown in its relative position by the general plan, Fig. 8. The leads for this purpose were 115 cm. long, made of twisted lamp cord, passed, for purposes of insulation, through a rubber tube, placed in turn in an iron pipe.

The galvanometer was designed and built by W. W. Coblentz. The four coils were connected in parallel, giving a resistance of 2.5 ohms. For electrical and magnetic insulation, the galvanometer was surrounded by a laminated iron cylindrical shell, close up, and by a series of three annealed soft iron pipes.

To use the galvanometer at all it was necessary to insulate it from mechanical shock. This was accomplished by mounting it upon a Julius suspension. The outstanding oscillations after this was done had an amplitude of only 0.2 or 0.3 mm. under good conditions, whereas, without the suspension, oscillations of several centimetres occurred.

Control of sensibility and zero position was secured, as is customary, by control magnets. The zero position was chiefly controlled, while observing, by a magnet beneath the galvanometer, turned by a long handle acting through two bevel gears. This control magnet could also be moved vertically, thus offering a ready means of changing the sensibility of the galvanometer over short intervals without disturbing the suspension. The other movable control magnets and the protective iron cylinders were all mounted upon the Julius suspension.

A wooden closet was built around the galvanometer and its accessories, serving for protection both against dust and aerial disturbances.

Calibration and Constants.

The sensibility of the galvanometer was determined by noting the deflection obtained when a Columbia dry cell was allowed to discharge through a specially constructed resistance furnished with the galvanometer. This resistance was placed in a glass tube, and the cell in a glass cylinder, sealed with paraffin. A bi-polar mercury contact, switch operated by the observer, controlled the circuit. The whole of the circuit was placed near the galvanometer and within the galvanometer enclosure.

The sensibility of the galvanometer most frequently used through this investigation was that when the period of the galvanometer was about 4 seconds. For special purposes the sensibility could be increased three- or four-fold. This could be maintained with difficulty, and for a short time only, on account of marked drift of the zero position. This drift is due chiefly to thermal conditions, but probably also to electrical and mechanical ones.

With the period of four seconds the drift was 3 or 4 cm. per hour, and under the best conditions somewhat less. The current sensibility of the galvanometer with a period of 4 seconds, as determined by the special circuit described above, was 0.37×10^{-10} ampères per millimetre deflection with the scale at one metre. The sensibility of the galvanometer, when adjusted for any given period, could be decreased by addition of resistance in series with it. This was done for the points in the spectrum of maximum energy—as much as 250 ohms being required at times to keep all deflections comparable. Linearity for small deflections was proved by the use of a sector disk.

On account of the drifting of the zero, and on account of certain uncontrollable thermal and electrical changes in the environment, all of which produced variations in the sensibility of the galvanometer, it was necessary to be able to ascertain the sensibility, irrespective of the position of the zero on the scale, and irrespective of the amount of resistance in the galvanometer circuit. For this purpose a 100-candle-power stereopticon point-source carbon filament lamp was mounted outside the spectrometer enclosure in front of a window into the enclosure.

A mirror, already mentioned, mounted near the focusing mirror formed an integral part of the spectrometer and reflected the radiation from this lamp on the thermopile. The mirror and the shutter which controlled the illumination on the mirror could be operated by the observer. The sensibility could thus be determined very readily at any instant. The carbon lamp was always operated at 100 volts, which gives approximately 4.85 watts per cm.^{2} per steradian.

Observational Procedure.

The burner and mantle were placed at a distance of about 10 cm. from the incident slit and immediately in front of the thick cast-iron plate and diaphragm already mentioned. The gas pressure was maintained at 3 inches by a governor near the burner. To eliminate slight effects which might escape the governor, a large capacity in the form of a 5-gallon tin can was inserted between the governor and the burner outlet.

Observations were made at intervals of 0.1μ for the most part; in a few cases intervals of 0.2μ were sufficient in the longer wave-length, while intervals of 0.01μ were necessary in the short wave-lengths in some instances. Five or more readings were necessary at every point to obtain values that could be successfully duplicated. With each sensibility employed a deflection was taken for the comparison standard radiation, and the mantle deflections were reduced to this standard deflection as a unit. With the "100-candle-power" stereopticon lamp used, at 100 volts (4.85 watts per cm.^{2} per steradian) this deflection unit corresponded to a sensibility of 0.329×10^{-10} ampères.

The observations by means of the infra-red apparatus extended through the region of the spectrum from 0.8μ to 14μ. Only on a few occasions could observations be made at shorter wave-lengths. There is thus a region from 0.7μ (end of visual work) to 0.8μ in which there are no observations, and which must be filled by extrapolation.

Reduction of Observation.

The observations as made all had to be reduced in accordance with the dispersion curve of the prism and the reflecting power of the three nickel-steel mirrors. After the reduction they gave *relative* energy value through the spectrum.

To give these relative spectral energy curves an interpretation in terms of ordinary units of energy and to compare them with the results given by total energy measurements determined by means of a surface thermopile, the following procedure was adopted:

The spectral energy curve of the ordinary Welsbach mantle was determined. The area of this curve, multiplied by the factor sought, was equated to the total energy so obtained, giving watts per cm.^{2} per micron, per unit solid angle as 0.0018, for the present set-up.

As a check on this a black-body furnace with an aperture of 3 mm. diameter was placed before the slit. The curve for the black body so obtained compared in relative values throughout the spectrum to 9μ satisfactorily with the black-body curve computed with the above constant.

5. *Measurement of Mantle Temperatures.*

A knowledge of the temperature of the mantle is of great importance. By use of the temperature it becomes possible to fix the emissive power or ratio of the emission to that of a black body at the same temperature. Without this knowledge it would be impossible to determine, except crudely, the exact characteristics of the mantle itself, irrespective of the particular temperature at which it is operated. Lack of temperature data has indeed been one of the chief deficiencies of much spectral emission work.

The exact determination of mantle temperatures is by no means an easy task. The temperature varies greatly from point to point, especially from top to bottom of the mantle (as much as 300°), and also from mantle to mantle, depending on adjustment, the way in which the mantle hangs, its age, etc. In order to reduce the range of possible uncertainty the regular temperature measurements made in this study were carried out as nearly as possible uniformly on the same part of the mantle, one-third the distance up from the bottom.

Three methods of temperature measurement were studied: (*a*) Optical, (*b*) by thermocouples, (*c*) by total radiation, as described below.

Of these, the most satisfactory was the second or thermocouple method, upon which chief reliance was placed, although the other methods gave support and confirmation when applicable.

(*a*) OPTICAL METHOD.

The optical method of measuring mantle temperature was employed by Rubens. He used it, however, in a manner which could only lead to correct results with a completely opaque, completely absorbing body, which the mantle is not, although the mantles rich in ceria approximate this condition in the blue end of the spectrum, to which Rubens confined the temperature observations on which he placed reliance. The method consists in general in measuring the black-body temperature by the usual method of equality of brightness used in the Holborn-Kurlbaum and Henning pyrometers, and then deriving the true temperature from a knowledge of the optical properties of the observed radiator.

If r_λ is the reflecting power of the body at wave-length λ, t_λ its transmitting power, E_λ its radiant emission, and J_λ the radiant emission of the black body at the same temperature, we have, from Kirchoff's law, that

$$E_\lambda = J_\lambda \ (1 - r_\lambda - t_\lambda)$$

provided the surface under study is continuous. If it is discontinuous (as, for instance. a grid of fine fibres would be), we have, if s represents the fractional part of the area occupied by the solid material, that

$$E_\lambda = J_\lambda \; s\,(1-r-t_\lambda)$$

Using Wien's law, this gives us for the true temperature T, in terms of the apparent or black-body temperature T_a

$$\frac{1}{T} - \frac{1}{T_a} = \frac{\lambda}{c_2 \log e} \log s\,(1-r_\lambda-t_\lambda)$$

In this formula the constants s, r, and t, refer, of course, to the properties of the *hot* body. It appears from the equation that T and T_a are more nearly the same the shorter the wave-length.

It is obvious that accurate temperature determination by this method would demand very elaborate measurements to establish the hot porosity, reflecting and transmitting powers. The best condition for using the method holds at the edge of the mantle, where by projection it appears continuous. Here s approaches the value unity. Also, by working near the edge of the mantle, r (cold) reaches its nearest approximation to the reflecting power of a thick opaque layer of the material in powdered form—which is capable of accurate measurement—and from which, by measurement of a bright image formed on the hot and cold mantle, the hot reflecting power is derivable.

The possibility of obtaining accurate results from the edge of the mantle, by assuming $t = 0$ and $r =$ the reflecting power of a solid layer of material, only exists if the assumptions are approximately correct. They will be so in the case of strongly absorbing substances, but it appears, from experiments made to test this point with various mixtures of thoria and ceria, that these assumptions are far from holding with most mantles. Thus in a series of mantles made up with continuous patches, formed by sewing small rectangles of filter-paper on the mantle fabric, it was found that when such a continuous patch was of such weight that when viewed normally it appeared upon measurement to have the same reflecting power and other optical properties as the edge of the mantle, it had a reflecting power, if of pure thoria, of only 0.55, while the solid material has a reflecting power of 0.85. Moreover, upon examining the brightness of the patch when illuminated both upon the illuminated and unilluminated sides, the latter was found to be over 50 per cent. of the former, showing that a very large part of the incident light is transmitted, even by the edge of the mantle. Thus neither can r be taken as that of the continuous layer of the mantle material, nor can t be taken as negligible, even when conditions are such as to make s = unity.

It therefore appears, as is borne out by our complete data, that the optical method, which should give accurate results for opaque layers of radiating material, is not practically applicable to mantles in general. The method gives substantially accurate and consistent results (as judged by the thermocouple readings) for mantles high in ceria in the yellow form throughout the shorter half of the visible spectrum, since in this case the cold material is fairly opaque in thin layers, and the mantle reflecting power cold is not greatly different from that of a solid layer. In the regular 99 per cent. thoria and 1 per cent. ceria mantle the black-body temperature and the temperature as corrected by inserting the hot reflecting power (ratio of hot to cold reflecting power × cold reflecting power of mantle material in continuous layer as above described), and neglecting its transmitting power, when determined for the extreme blue, differ from each other and the thermocouple temperature by amounts less than the uncertainties of the latter measurements. In the case of the pure thoria mantle, however, the nearest approach to the true temperature that the method gives, even if r and t are assumed to amount together to the reflecting power of an opaque layer, namely, 85 per cent., falls short of the thermocouple temperature by as much as 100°. This failure is in part due to the error in the value of r and t assumed for the cold mantle, and in part perhaps to an actual increase of transparency with increase in temperature. In either case accurate results could be attained only by measuring the true reflecting and transmitting powers of the heated mantle—a task of very great complexity and difficulty.

(*b*) THERMOCOUPLE METHOD.

The most satisfactory method of temperature measurement, on the whole, is that which utilizes a series of thermocouples of graduated size, first used by Nichols for flames, and later by White and Travers [6] for the incandescent mantle.. The theory in its simplest form is that, while a single thermocouple will not give correct readings, due to the heat it radiates and conducts away, this error is less the smaller the couple, and so by using a series of decreasing size the value which would be given by a couple of zero mass may be fixed by extrapolation.

Our temperature measurements were carried through with couples of platinum-platinum-rhodium of diameters 0.35, 0.25, 0.15, and 0.05 mm. secured from Engelhardt, and drawn from the same stock. One of these was calibrated by the Bureau of Standards, and the calibration was assumed to hold for all. Certain precautions were observed in their use, some obvious and some learned from experience. As great a length as possible of the couple should be against the mantle, so that the temperature at the junction is affected a minimum amount by conduction to the cooler portions not in contact. The "bead" should be as nearly as possible of the same diameter as the wires which it joins, so that the diameters assigned in plotting shall be correct. After continued use the couples may give inconsistent results, as though one or more had become contaminated in some way. Upon cutting off the beads and forming new ones the trouble is usually overcome.

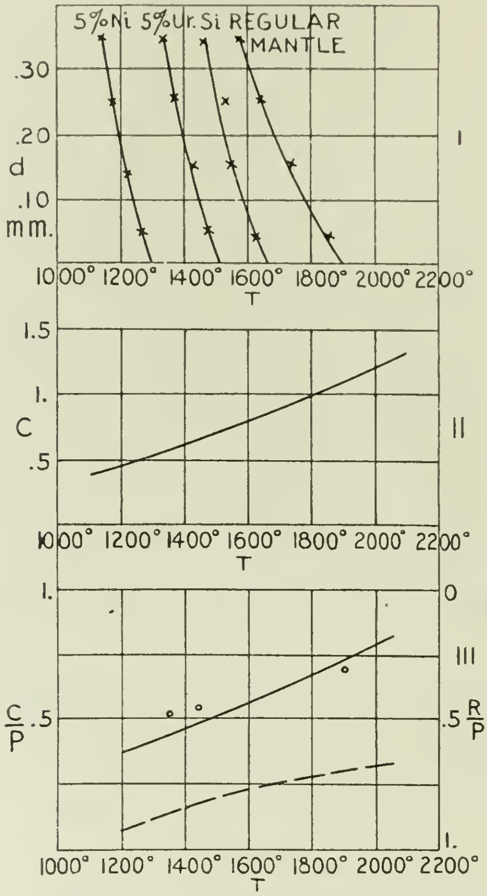
It has ordinarily been assumed that the points given by such a series of thermocouples lie on a straight line. Our results on the couples described indicate rather consistently that these points lie on a curve. Some representative results are shown in Fig. 9 (*I*) for mantles of several temperatures. The curvature spoken of is well shown, and it appears as well that with the lower temperature mantles the curve is more nearly perpendicular to the temperature axis; *i.e.*, the various couples differ less in their readings.

These characteristics of the thermocouples of varying diameter are accounted for rather satisfactorily if it is assumed that they may be considered as cylindrical wires to which heat is conveyed through thin films of hot gas, of thickness independent of the temperature and size of the wire. Similar assumptions have been shown to be valid by Langmuir [7] for the case of heated wires losing their heat to a surrounding atmosphere at a much lower temperature. The thickness of the effective gas film in that case, namely 0.43 cm., is too great to be assigned easily to the thermocouple against a mantle, and if a much smaller thickness is assumed it becomes necessary to obtain independent experimental proof of its effective constancy of thickness, especially under the very different temperature differences in question. The possibility for such a theoretical support of the character of the curve needs merely be noted here; for the present purpose it is sufficient to utilize the experimental fact that satisfactory temperature measurements are obtainable from a series of couples by extrapolation.

(*c*) RADIATION METHOD.

It was found experimentally, from the measurements made on the total radiation from mantles, that the radiation for con-

FIG. 9.



I. Measurement of mantle temperature by thermocouples of graduated diameter: *d*. Thermocouple diameter. *T*. Temperature.
II. Relative convection losses at various temperatures as calculated from the conducting film theory: *c*. Convected energy.
III. Convection losses as calculated from specific heat of products: *C*. Convected energy. *P*. Applied energy. *R*. Radiated energy. Full line—Combustion in air. Dashed line—Combustion in oxygen.

stant gas consumption was not constant, *but decreased with increasing mantle temperature.* Thus a black bulb thermometer placed so as to be heated in turn by the radiation from mantles of various compositions would exhibit the apparent anomaly of showing the greatest temperature rise for the mantle of lowest temperature. A relationship of this sort, besides demanding explanation, offers a possible method of temperature measurement.

The explanation lies in general in this fact, that for a given constant consumption of gas (rate of supply of energy) the portion of the total power which is dissipated by convection and conduction is greater the higher the temperature, consequently the rest of the applied energy, which can escape only as radiation, must be smaller the higher the temperature. The behavior of the complete burner-mantle combination may be handled in two different ways. One way is on the assumption, found well confirmed by Langmuir, that the convection of heat away from a surface takes place as though there were a stationary film of gas, of thickness independent of the temperature of the surface, through which the heat is carried entirely by conduction. The second way is to consider the products of combustion as leaving the surface of the mantle at the mantle temperature, and then from the specific heat of these products to calculate the heat thus carried away. In each case the radiation is the difference between the energy consumption and the convection-conduction loss.

Taking up the first mode of treatment, if we call the thickness of the gas film t and its conductivity K, and if the temperature of the mantle surface is T_m and that of the surrounding atmosphere T_a, we would have for the energy conducted away, C, if K were a constant.

$$C = \frac{K}{t} (T_m - T_a)$$

Actually K is not a constant, but varies with the temperature; it is therefore necessary to substitute for kT the quantity $\int_0^T k\, d\vartheta$ which may be called ϑ so that we have

$$C = k_1 (\vartheta_2 - \vartheta_1)$$

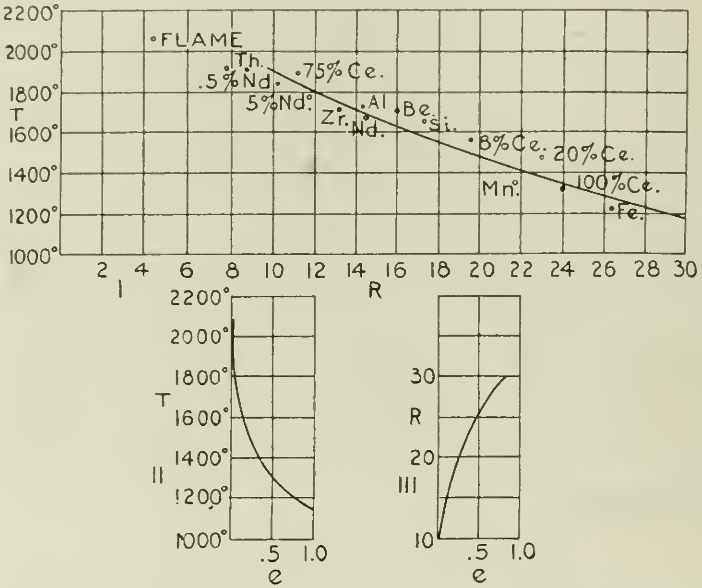
where k_1 is a constant. Now values of ϑ in energy units have been calculated by Langmuir for hydrogen, air, and mercury vapor, the curves connecting T and ϑ being of similar shape but different absolute value for these three gases. Upon taking the values for air, assigning the value 300° K. to ϑ, and using temperatures from 1100° to 2100° K. (range covered by ordinary mantles), the data shown in Fig. 9 (II) are obtained. It will be seen that these differ but little from a straight line. The radiation R will be as stated above—

$$R = P - C = P - A\ (T_m - T_a)$$

where P is the applied energy, so that if P is a constant, R will be represented as a very closely rectilinear function of T_m, the mantle temperature.

The second method of treatment is considered at length below in connection with the question of the total efficiency of the mantle and burner. For the present purpose it is only necessary to refer to Fig. 9 (III) to see that this same nearly rectilinear relation between temperature and convection losses is indicated, and hence the same form of relation between temperature and radiation.

FIG. 10.



I. Experimentally found relation between temperature and radiance: *R*. Radiance in arbitrary units. *T*. Temperature.
II. Relation between emissive power and temperature: *e*. Emissive power. *T*. Temperature.
III. Relation between emissive power and radiation: *e*. Emissive power. *R*. Radiance, in arbitrary units.

Experimental confirmation of this relation is shown in Fig. 10 (I) where total radiation measurements are plotted against temperatures as found by the thermocouple method. In view of the fact that the linear relationship is only to be expected if the consumption is constant, and if the mantle forms the outer surface of the heated "body," and that actually the mantles were ordinarily adjusted to give the maximum luminosity, irrespective of exact consumption, or whether the flame did or did not strike through the mantle—which, moreover, is not a continuous but a porous body—the agreement with the theoretical treatment is good. The straight line fixed by several well-determined thermocouple points thus constitutes a plot from which temperatures may be determined from radiation measurements.

As a further step an emissive-power-temperature relationship follows from the same data, for, if e is the emissive power, and the Stefan-Boltsmann constant, R the radiation

$$\mathrm{R} = e\sigma \left(T_m^4 - T_a^4\right)$$

or

$$e = \frac{R}{\sigma \left(T_m^4 - T_a^4\right)}$$

Now, R and T both being given in the plot of Fig. 10 (I), e as a function of T is readily calculated, giving a relationship of the form shown in Fig. 10 (II), which is plotted through the measured emissive powers as determined by the direct methods already described.

A point of some interest is brought out by developing the relation between emissive power and radiation, upon substituting T_m in terms of R and P, which give

$$e = \frac{R}{\sigma\left[\left(T_a - \frac{R-P}{A}\right)^4 - T_a^4\right]}$$

This relation shows that e may be expressed as a function of R as the only variable. Fig. 10 (III) shows the relationship plotted from the previously used data.

Under the conditions holding in the mantle, therefore, with its constant rate of supply of energy, the smaller the radiation the higher the temperature and the lower the emissive power, and once the constants in the relationship have been established, the single measurement of radiation establishes the value of all three quantities.

Obviously, from the experimental data shown, the conditions holding with the various mantles are not uniform enough to make the radiation measurement in combination with the plotted mean curve a precision method of temperature or emissive power determination. It does, however, give a useful check on other measurements, and has been found valuable in that way. For instance, a series of infra-red emission curves, made upon a series of similar mantles composed of graduated mixtures of two oxides, may be assigned their relative temperatures very satisfactorily from their areas. The method of fixing emissive power by a radiation measurement is capable of application to the study of substances in some other than mantle form.

6. *Measurement of Reflecting Power.*

Some of the oxides studied showed the interesting property of changing their optical properties on heating. In other cases mixtures of oxides showed color characteristics different from that of their constituents. In order to record these properties measurements were made through the visible spectrum (1) on the reflecting power of the mantle material cold, in powder form, and (2) of the change of reflecting power of the mantle upon heating.

The cold reflecting power of the mantle material was measured by means of a spectrometer and potassium photo-electric cell. All measurements were made in terms of magnesium oxide as a standard white, two shallow cups being provided which could be alternated before the spectrometer slit, and which, when in that position, were illuminated by the focused image of a concentrated filament tungsten lamp. In order to reduce the reflecting power to absolute values the diffuse reflecting power of magnesium oxide has been taken as 85 per cent.

For the measurement of the change of reflecting power upon heating, the spectropyrometer previously described (Fig. 4) was employed, in conjunction with a carbon arc lamp, *C*, used to give an image of the carbon crater for projection on the mantle. The carbon arc image was formed by a projection lantern condenser, the light passing through a water tank, and falling on the edge of the mantle under observation, the line of projection being made as nearly coincident with the line of observation as possible.

The procedure found best by trial was first to set the spectropyrometer on the incandescent mantle, taking the reading; then with the mantle unlighted to adjust the arc image until it matched in brightness the pyrometer lamp as held to the mantle value; finally, the mantle was again ignited and a setting made on the mantle and arc image combined brightness. From these three settings it is at once possible by translating the black-body temperatures into intensities, to obtain the hot reflecting power in terms of the cold.

7. Determination of Emissive Power.

In order to obtain the emissive power of a substance it is necessary to know its radiant emission and its temperature, from which the radiant emission of the black body at the same temperature may be calculated, thus giving the two quantities whose ratio is desired.

The total emissive power is given by combining total radiation measurements made as previously described, in absolute measure, with the corresponding emission of the black body as calculated from the temperature. In the case of the wave-length distribution of emissive power, one possible process would be to make observations on a black-body opening subtending the same angle as the measured portion of the mantle. From this observation black-body emission curves could be constructed for other temperatures, and comparisons then made wave-length by wave-length. Another process is to measure the area of the normally plotted emission curve and then draw on the same wave-length scale the emission curve of the black body at the mantle temperature with such ordinates that the area of mantle and black-body curves is as found by the radiation measurements. The ratio of the curves at each wave-length gives the desired emissive power.

In the visible spectrum the emissive power is obtained at once from the optical pyrometer measurements by comparing the brightness pertaining to the apparent black-body temperature to the brightness of the black body at the true temperature of the mantle. With ideal precision of measurement, or such an approach thereto as could be obtained if both infra-red and visible measurements were made simultaneously and conditions were exceedingly steady for the infra-red end, it should be possible to make readings in the red end of the spectrum overlap, whereby the comparatively easy determination of emissive power in the visible region could be made to serve as a starting-point for the continuation into the infra-red.

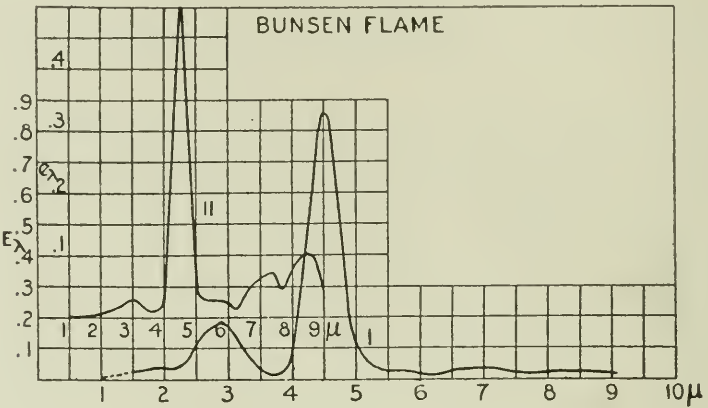
Actually the method upon which most reliance was placed was the second, but a reasonably close agreement of the infra-red and visible emission measurements at their junction point when corrected to the same temperatures was demanded (so as to be within the possible temperature and other variations in making either sets of observations) before these were reduced to emissive powers.

The emissive power wave-length curves as plotted are all referred, as in the case of the emission curves, to the porous centre of the mantle.

8. *List of Quantities Measured in Complete Study.*

The routine measurements made on each mantle were eight in number, and may be tabulated here, before the detailed discussion of each mantle is undertaken.

FIG. 11



I. Spectral distribution of emission in the Bunsen flame.
II. Spectral distribution of emissive power in the Bunsen flame.

The various measurements are as follows:

1. Temperature, T, in centigrade degrees absolute (Kelvin).
2. Total radiation, R, in watts per cm.^{2} per steradian (radiance).
3. Total emissive power, e.
4. Radiant luminous efficiency, $\frac{L}{R}$.
5. Spectral distribution of radiant emission E_λ in watts per cm.^{2} steradian per micron wave-length interval.
6. Spectral distribution of emissive power, e_λ.
7. Spectral distribution of reflecting power of mantle material, x_λ.
8. Ratio of reflecting power hot, to reflecting power cold, $\frac{r^h}{r^c}$.

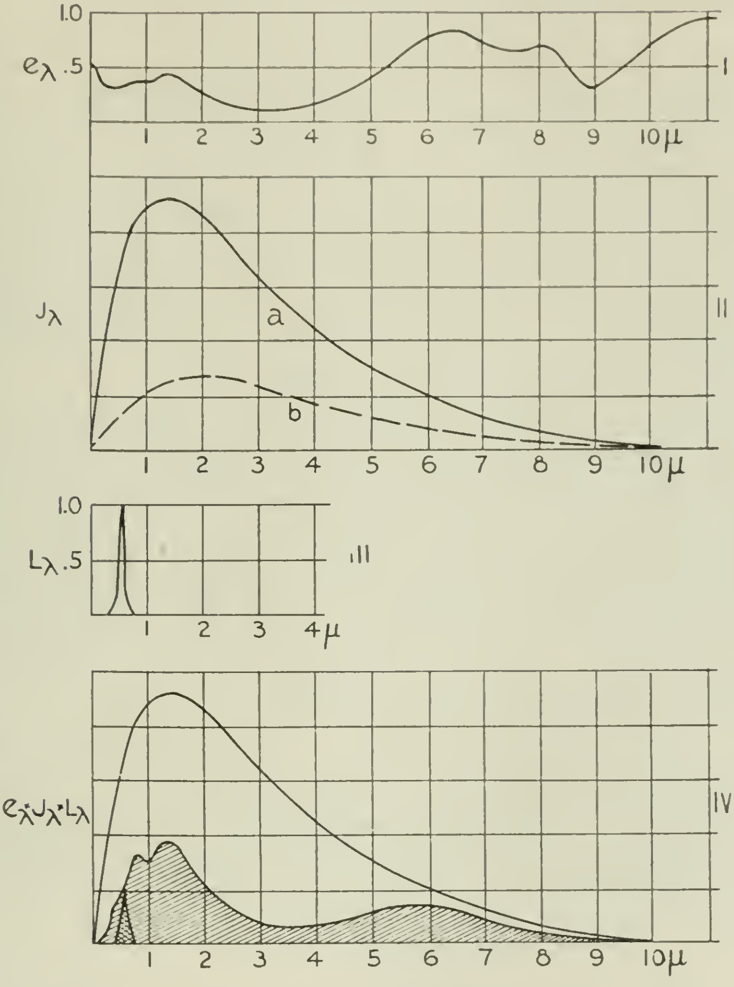
V. CHARACTERISTICS OF THE BUNSEN FLAME.

The Bunsen flame, as the "base" and source of heat for all the mantles, and hence always present, must claim first attention among mantle materials, although itself of negligible value as a light-source.

The values of the tabulatable quantities are as follows:

T	R	$\frac{L}{R}$	
2050°	.43	Negl	0.0116

FIG. 12.



Diagrammatic representation of selective temperature radiation:
I. Spectral distribution of emissive power in an assumed substance.
II. Spectral distribution of emission for a black body at high (*a*) and low (*b*) temperatures.
III. Luminosity curve of the equal-energy spectrum.
IV. Emission (cross-hatched curve) and luminous emission (double cross-hatched curve) of radiator I, at temperature which gives black body emission at (II).

The spectral distribution of radiant emission is shown in Fig. 11 (I). It is characterized by maxima at 1.95μ, 2.9μ, 4.52μ, 5.6μ, 7μ, and 8.35μ, of which the one at 4.5μ (CO_2) is the most conspicuous. This band is a characteristic feature of all mantles heated by the flame.

In the same figure, on a different scale, is shown (II), the emissive power distribution e_λ, which is everywhere low except for the band at 4.5μ, which is high, but because of its narrowness does not contribute enough to make the flame other than a very poor radiator.

VI. GENERAL THEORY OF MANTLE LUMINOSITY AND METHOD OF CLASSIFYING MANTLE MATERIALS.

1. The Ideal Mantle.

The radiant luminous efficiency of any radiator is a function of its emissive power and its temperature. The temperature attained may itself be a function of the total emissive power. This is the case, for instance, in the gas mantle, where the heat is supplied from another body (flame) whose temperature places an upper limit to the temperature of the luminous radiator, to be approached only by a radiator of very low emissive power, but little cooled by its loss of heat by radiation.

Considering the problem first without regard to the method of heating, the luminous efficiency is found by the combination of three elements: (1) The emissive power of the radiator, which is some function of the wave-length, say, e_λ, represented for an arbitrary substance by Fig. 12 (I); (2) the radiant emission of the black body at the temperature assumed by the radiator, which is another function of the wave-length, say J_λ, represented for two different temperatures by the curves (*a*) and (*b*), Fig. 12 (II); (3) the luminosity curve of the equal-energy spectrum, which is another function of wave-length, say L_λ, represented in Fig. 12 (III). The radiant emission of the radiator is the integral of the product at each wave-length of (1) and (2) or

$$R = \int_0^\infty e_\lambda J_\lambda d_\lambda$$

represented by the cross-hatched curve, Fig. 12 (IV).

The luminous emission is the integral of the product of each wave-length of (1), (2), and (3), or

$$L = \int_0^\infty L_\lambda e_\lambda J_\lambda d_\lambda$$

represented by the double cross-hatched curve, Fig. 12 (IV).

The luminous efficiency of the radiated energy is now

$$\frac{L}{R} = \frac{\int_0^\infty L_\lambda e_\lambda J_\lambda \, d\lambda}{\int_0^\infty e_\lambda J_\lambda \, d\lambda}$$

Of the factors in this equation, L_λ is fixed by the characteristics of the human eye, J_λ is fixed by the absolute temperature, being defined by the Wien-Planck equation, while e_λ is a characteristic of the substance used in the radiator, and may in general have any value between zero and unity. The two underlying factors which may be varied in a luminous radiator therefore reduce to *temperature* and *composition.* In so far as temperature is concerned—neglecting for the present the limitations to attainable temperature set by the manner of heating, and the practical limitation set by the melting or volatilization of the material of the radiator—the luminous efficiency of the radiator increases with very great rapidity as this is increased. This follows from the characteristics of the black body, whose emission curve through the spectrum as shown in Fig. 12 is always the "envelope" of the emission curve of any radiator at the same temperature. As is well-known, and expressed by the Wien-Planck equation,

$$J_\lambda = C_1 \frac{\lambda^{-5}}{e^{\frac{c_2}{\lambda T}} - 1}$$

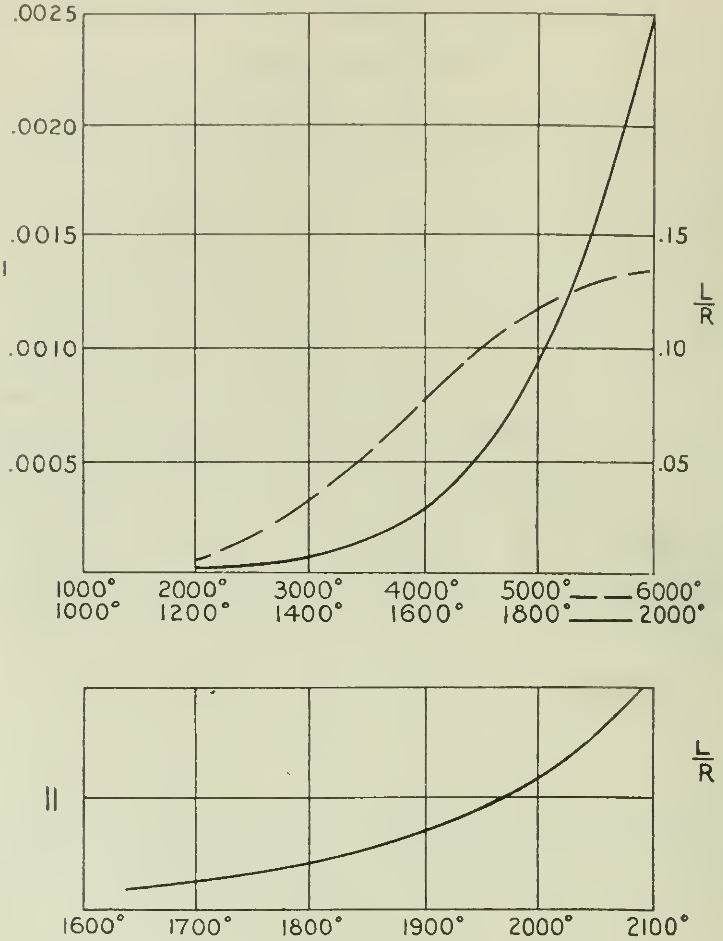
not only does the total radiant emission of the black body increase rapidly with temperature (as the fourth power), but the emission for the shorter wave-region of the spectrum (the visible end) increases with by far the greater rapidity, according to the equation:

$$J_\lambda = C_1 \lambda^{-5} e^{-\frac{c_2}{\lambda T}}$$

which in the case of visible energy, for temperatures around 1800° K., is equivalent to the thirteenth power of the temperature. Consequently, as the temperature increases, the short wave (visible) energy emission is favored. Hence, with any radiator whose emissive power has finite values throughout the whole spectrum, the greatest luminous efficiency is attained at high temperatures. Fig. 13 (I) shows the relationship between luminous efficiency and temperature for a black body, which reaches its maximum (13.5 per cent.) at about 6500° K.

Considering next the effect of the spectral distribution of emissive power of the radiator, it is obvious that no radiator

FIG. 13.



I. Radiant luminous efficiency of the black body at various temperatures.
II. Relative radiant luminous efficiency of the regular mantle at various temperatures obtained by oxy-gas heating.

promises improvement in light-production unless it has an emissive power in the visible region of the spectrum, *relatively* high as compared with the rest of the spectrum. If it is the same as elsewhere in the spectrum, the body is gray; *i.e.*, it has the same efficiency as the black body, which is lower, at temperatures now available, than many light-sources in use. The ideal to be sought from the standpoint of light production is a radiator which shall have *no* emissive power except in the visible region, and maximum emissive power there, preferably, if mere efficiency is desired, all concentrated on the wave-length of maximum visibility. Were such a radiator attainable, it would have maximum (unit) radiant luminous efficiency, irrespective of temperature. This ideal is not in sight at present, but a radiator which approximates in any degree thereto is more efficient than a black body at the same temperature, and, like it, increases in efficiency with increased temperature. The increase in efficiency may be more or less rapid than with the black body, depending on the values of e_λ.

There is a second reason for aiming toward a spectral emissive power distribution of the ideal type discussed, which is in a way peculiar to the method of heating employed by the gas mantle. This is that by this type of emissive power the temperature attained by the mantle by contact with the flame approaches most nearly the upper limit set by the temperature of the flame. This follows at once from the consideration that the lower is the emissive power as a whole the less loss of heat there is from the mantle by radiation, and hence (*provided this gain is not offset by increased convection or conduction losses*) the higher the temperature it can maintain.

From every standpoint, therefore, it is clear that the desirable mantle materials, in so far as radiating properties are concerned, *are those of high emissive power in the visible region, of low emissive power elsewhere.*

2. *Radiation from Mixtures of High and Low Emissive Powers.*

Fortunately for the gas-mantle industry, the available materials have not been restricted to single refractory compounds possessing the characteristics just outlined. It has been found possible to obtain in *mixtures* properties which neither material possess alone, or, put differently, to obtain in some degree a combination of the desirable qualities of several materials, to the partial exclusion of their undesirable ones. Such mixtures consist, as a rule, of an oxide having low general emissive power in the visible region (base), combined with one having high emissive power in the visible region (*colorant*). The proper proportion of the mixture is that which secures the optimum luminous efficiency: as conditioned on the one hand by the rise of visible emissive power due to the colorant, on the other hand, by the drop in the temperature assumed by the mantle in the flame due to the increasing radiating power of the mixture as the amount of colorant is increased.

It is a general characteristic of such mixtures that their luminous efficiency rises to a maximum and then decreases as the amount of colorant is continuously increased. This may be illustrated by a simple hypothetical case. Let us imagine a highly transparent base of low radiating power, which gives no light (*i.e.*, visible emission), upon which black particles are sprayed. Before the addition of the black particles the base, because of its low emissive power, assumes very nearly the temperature of the heating flame. The first few black particles, assuming practically this temperature, glow brilliantly. Now as more particles are added the effective radiating surface increases, with consequent more light. But, at the same time, the temperature of the mixture is pulled down by the increased radiation, so that the luminous efficiency of the black particles decreases. The mixture-light curve is hence the resultant of two opposing effects. For the case considered it may be approximately calculated in terms not of mixture proportions, but of effective radiating area of black particles, which is, of course, a function of mixture proportions. Thus, if we assume, for the sake of simplicity, that the total energy radiated by the assumed mantle is constant (instead of increasing with decreased temperature), we have that its temperature for any black radiating area a is given by the relation:

$$(a+a_0)\,T_1^4 = a_0 T_0^4$$

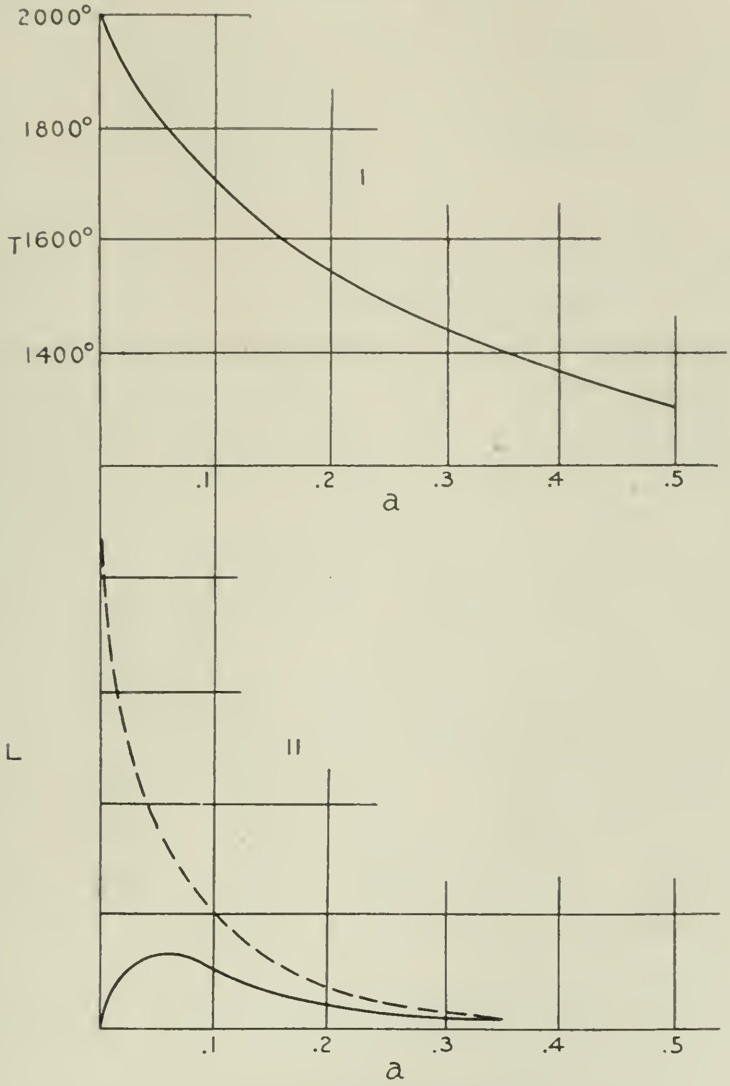
$$\frac{T_1}{T_0} = \sqrt[4]{\frac{a_0}{a+a_0}}$$

where a_0 = emissive power of base, T_0 the temperature assumed by the base, and T_1 the temperature assumed by the mixture.

Now the luminous value of these black particles is given by the light emitted by the black body at the temperature of the mixture, which is known, times the radiating area of the particles. The various steps of this calculation are shown in Fig 14, I and II. In I is shown the variation of temperature with a, assuming the base of emissive power 0.1 to take the temperature of 2000° K. in the flame. In II are shown (dashed line) the luminous value of the black body at temperatures of 2000° and below, and (full line) the product of *a* and *L* against *a*, *L* being taken for the appropriate temperatures as given by *I*.

It is shown by this calculation that with the assumed constituents a luminous efficiency (light-output to energy output) can be secured higher than either constituent—represented by the values 0 and 1 of *a*—can give. In the last analysis this will be found in the case of the black-body colorant assumed to be merely a consequence of the fact that, while the total radiation varies as the fourth power of the temperature, the luminous radiation

FIG. 14.



Theory of mantle luminosity:
I. Decrease of temperature with increase of emissive power.
II. Variation of luminous emission with increase of emissive power.

varies as the eleventh or twelfth power of the temperature in the region near 2000° K. In other words, it is more economical, from the standpoint of light-production, to use the heat available for heating a small quantity of matter to a high temperature than a large quantity to a low temperature. Given a limitation of temperature and available energy, the kind of mixture assumed constitutes the most effective mode of utilizing black-body radiation. Similar reasoning will show an optimum ratio of mantle fibre to opening. The wider the mesh the higher the temperature assumed, but the smaller the light-giving surface. It is easily seen that the efficiency for the case considered is always less than that of the black body at the same temperature, hence the mixture of black particles with a transparent base would be of interest only if quite high flame temperatures were practically available—the luminous efficiency of the black body at the temperature of the ordinary Bunsen (2050° K.) is no longer attractive in the study of light-production. The case is quite different, however, if the colorant is of higher emissive power in the visible than in the infra-red region, and particularly so if this selective character is more marked for small amounts than for large. If, for instance, the coloring material, instead of being considered as in the form of scattered opaque particles, is in the form of a generally transparent medium dissolved in the base, but possessing a single absorption band located in the visible region, then, in place of an increase of radiating area with increased quantity as above assumed, there would be, in consequence of the general characteristic of absorption bands, an increase in width of the band in the spectrum. The same phenomenon of passing through an optimum would be exhibited as the band entered the infra-red, but the maximum efficiency and the final efficiency for such a coloring material would be higher than could be obtained by mere black coloring, and higher the narrower and more pronounced the absorption band. It will be seen below that the regular thoria-ceria mantle conforms closely to the kind of mixture just described. It follows from this reasoning that any colorant—*i.e.*, any material of relatively high visible emissive power, short of the ideal material discussed previously—is most efficiently utilized in a flame of fixed temperature if it can be mixed with a certain proportion of material of considerably smaller emissive power.

3. *Classification of Mantle Materials.*

A rather definite basis of classification of the mantle oxides here studied may be made according to whether they possess high or low emissive power in the visible spectrum. If their emissive power is low they are either of no use in light-production or are of use as bases for coloring materials. If their visible emissive power is high they are of promise either alone or as coloring materials. The materials of the first class are best studied alone. The second class must be studied in their series of mixtures, with bases of low general emissive power—preferably, of course, with the base of lowest emissive power known.

VII. MANTLES COMPOSED OF OXIDES OF RELATIVELY LOW EMISSIVE POWER IN THE VISIBLE SPECTRUM.

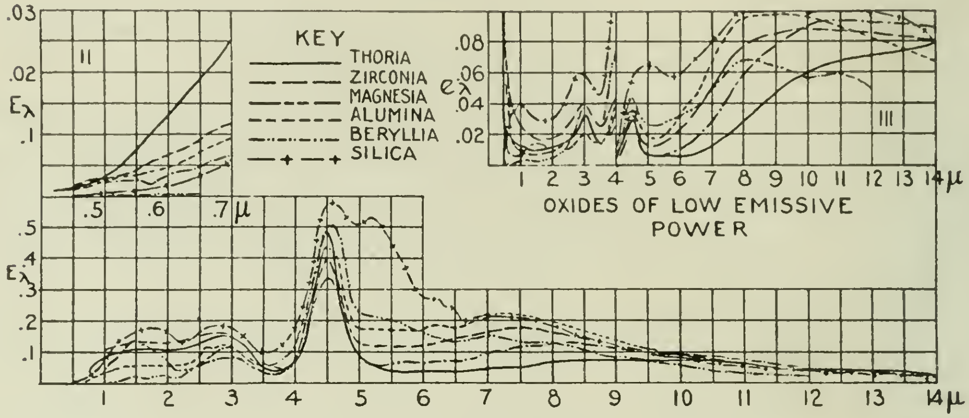
Six of the mantles studied were of such relatively low visible emissive power as to be clearly useless alone for light-production, and of no promise as colorants. These were Thoria, Zirconia, Magnesia, Alumina, Silica, Beryllia. A tabulation of their characteristics follows:

Material	Weight of mantle, grammes per cm.²	T	R	e	$\frac{L}{R}$	$\frac{L}{R}$ Compare to *BB* at same temperature
ThO_3.......	.0090	1930°	1.1	.044	.00032	.2
ZrO_2........	.0060	1670°	1.32	.095	.000143	.36
MgO.......	.0082	1840°	1.1	.053	—	—
Al_2O_3.......	.0065	1725°	1.41	.088	.00039	.7
SiO_2........	.0046	1650°	1.71	.13	—	—
BeO........	.0032	1690°	1.61	.11	—	—

In Fig. 15 are shown the spectral emission, I and II, and the spectral emissive power, III, of these six mantles. It will be noted that, while this whole group of mantles is characterized by low visible emissive power, all giving very little light, they yet differ very widely in their total emissive powers and the temperatures which, as a consequence, they maintain in the flame. At one extreme lies Thoria, which assumes a temperature of 1930°, 120° below that of the flame. Next to it, but much inferior, lies Magnesia, with a temperature 90° lower. At the other extreme lie Silica and Beryllia, assuming temperatures of

1650° and 1690°. These latter are striking examples of substances possessing properties almost exactly complementary to those desired in light-production, for both by the low temperature assumed and by the distribution of emissive power with all the higher values in the infra-red of the spectrum the probability of attaining any considerable luminous efficiency is ruled out. Zirconia is similarly of no promise because of its low temperature, although, because of its relatively higher visible emissive power, it makes a better showing as a light-producer than do the others of nearly the same temperature.

FIG. 15.



Oxides of low general emissive power:
I. Spectral distribution of emission.
II. Spectral distribution of emission (visible region).
III. Spectral distribution of emissive power.

The fact that stands out prominently from this set of data is the striking superiority of Thoria as a mantle structure. From the spectral emissive power curves it appears that as the temperature is raised, so that the long-wave portion from 5μ outward has less effect on the emission, Magnesia should become as good as, or even better than, Thoria, since its emissive power below 5μ averages less than that of Thoria.

Because of the clear superiority of Thoria as a base, the experiments on oxide mixtures were all made on mixtures with it.

(*To be continued.*)

ON THE DISTRIBUTION OF THE ENERGY STORED IN REINFORCED CONCRETE BEAMS AND COLUMN-SUPPORTED, FLAT-SLAB FLOORS.

BY

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1. SINCE the most accurate and complete test data available respecting reinforced concrete beams is found in Technological Paper No. 2, U. S. Bureau of Standards,[1] in which are given details of tests upon 333 of these beams, for convenience of comparison the developments in this paper will deal with beams reinforced and loaded in the same manner as those in this Paper No. 2.

The beams in Paper No. 2 had a span between supports of $l = 12$ ft., a width of $b = 8$ in., a total depth of 11 in., and a depth to the centre of the bottom layer of steel of $d = 10$ in., a total actual length of 13 ft., a uniform reinforcement from end to end, and equal concentrated loads $= \frac{1}{2}\, W$ placed at each of the one-third points of the span. The reinforcement consisted of half-inch round rods from two to eight in number, of mild steel with an elastic limit between 33,000 and 41,000 lbs., a yield point between 35,000 and 43,000 lbs., and an ultimate strength between 52,000 and 64,000 lbs.

The reader is referred to the paper itself for the numerical results of the tests, except so far as herein quoted, as well as for the details of the construction of the beams.

2. Let M designate the bending moment, I the moment of inertia, R the radius of curvature, k the proportional depth of the neutral axis, and D the deflection at mid span. None of these quantities except D vary in value between the one-third points, and they also have nearly the same values in the end thirds for some distance from the one-third points toward the ends. Especially is this the case with I and k, as may be known from Figs. 22 to 30, inclusive of Paper No. 2, which reveal the fact that the cracking of the concrete by tension extends throughout almost

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[1] By Humphrey and Losse, Government Printing Office, Washington, 1912.

the entire length of the beams, except for a short distance near each end, where the bending moment is so small that the variations in the value of I and k by reason of no cracking have a negligible effect.

Let $A = pbd$ be the cross section of the reinforcing steel in square inches, when p = the steel ratio. Let kd = the depth of the neutral axis below the top of the beam and $i = 1 - k$; also let jd = the depth of the centre of action of the steel below the centre of compression of the concrete. In Paper No. 2, the parabolic law of compression is assumed, *i.e.*, $j = 1 - \frac{3}{8}k$, whereas for straight line compression $j = 1 - \frac{1}{3}k$.

If we assume that the concrete is so cracked that the steel supplies the only tensile resistance, we have from the fundamental equation of flexure, $EI/R = M$, in which the applied bending moment $M = \frac{1}{6} Wl$ throughout the middle third of the span, Hence,

$$EI = \tfrac{1}{6} WlR \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

But by the similar triangles of the distortion of bending

$$e_s : id :: 1 : R, \text{ or } R = id/e_s = Eid/f_s \ldots\ldots\ldots\ldots (2)$$

in which $e_s = f_s/E$ is the unit elongation of the steel, E its modulus of elasticity, and f_s the unit stress.

Hence,

$$EI = MR = \frac{id}{6e_s} Wl \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

By the usual methods of finding the deflection of beams from their curves of flexure we find the value of the deflection D' at a one-third point of the span from the expression

$$EID' = \frac{Wl^3}{432} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and for the total deflection D at mid span

$$EID = \frac{23\,Wl^3}{1296} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Hence,

$$D - D' = 0.87D \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

or each one-third point moves downward in bending 87 per cent of the total deflection D at mid span.

Now substitute the value of EI given in (3) in (5) and we have

$$D = \frac{23}{216}\frac{l^2 e_s}{id} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

in which it is tacitly assumed that the mean value of I used in integration in finding the beam deflection in (5) does not differ from the value of I in the middle third as used in (3) by more than a negligible amount. This assumption has been verified as practically admissible by a more complete analysis based on the exact and somewhat larger values of I that occur near the ends of the beams due to concrete and steel acting together, with the resulting larger values of k. It is found that the effect of this upon the ratio 0.87 in (6) may be safely neglected, since although $D-D'$ and D may be changed by small amounts their ratio will be affected by only an inappreciable amount.

Now the work performed by the load and expended upon the beam in the process of gradually loading it is expressed as follows:

$$U = \tfrac{1}{2}W(D - D') = 0.435WD \quad\ldots\ldots(8)$$

in which $D-D'$ is the vertical distance moved through by the load in performing its work. Consequently by (7)

$$U = \frac{10\, W\, l^2 e_s}{216\, id} \quad\ldots\ldots(9)$$

Again, the work stored in the steel of the middle third of the span may be written

$$U_s = \tfrac{1}{6}\, Alf_s\, e_s \quad\ldots\ldots(10)$$

in which $\tfrac{1}{3}Al$ is the volume of the steel and e_s its unit elongation. But since the moment of resistance of the steel is equal to the moment of the applied forces we have

$$Af_s\, jd = \tfrac{1}{6}\, Wl \quad\ldots\ldots(11)$$

Therefore,

$$U_s = \frac{W l^2 e_s}{36\, jd} \quad\ldots\ldots(12)$$

Hence,

$$\frac{U_s}{U} = \frac{216\, i}{360\, j} = 0.6\frac{i}{j} \quad\ldots\ldots(13)$$

In case we assume for the moment that $k = 0.4$, which is a good average value for the beam tests in Paper No. 2, we have $i = 0.6$ and $j = 1 - \tfrac{3}{8}k = 0.85$. Then $U_s/U = 0.4235$ is the fraction of the total work of the load which is stored in the steel in the middle third.

It will be fair to estimate the work stored in the steel in the two end thirds as one-half of this amount, because were the same relation to exist in the end thirds between the applied bending moment and the resistance of the steel as in the middle third, then the energy stored in the steel in each end third, and due to a moment uniformly decreasing to the end, would be one-third that in the middle third. But, owing to the existence of tensile resistance in the concrete near the ends, the stresses on the steel are thereby reduced somewhat below one-third, and the amount of work expended upon the steel in each end third may reasonably be taken as reduced to not more than one-fourth that in the middle third or possibly to even less than that, thus giving as an estimated ratio of the total work stored in the steel of the entire span to the work of the load the quantity.

$$\frac{3}{2}\frac{U_s}{U} = 0.9\frac{i}{j} \dots\dots\dots\dots \quad (14)$$

or in case $k = 0.4$, we have

$$\frac{3}{2}\frac{U_s}{U} = 0.635$$

This is considerably more than one-half of the total work of the load, being some five-eighths of it.

3. The work U_c expended in compressing the concrete of the middle third and stored in it during loading may be calculated in like manner. For on the assumption that beam sections originally plane remain plane after flexure we have

$$\frac{id}{e_s} = \frac{kd}{e_c} \dots\dots\dots\dots \quad (15)$$

Hence by (7)

$$D = \frac{23\, l^2 e_c}{216\, kd} \dots\dots\dots\dots \quad (16)$$

But U_c is half the product of the total amount of the reduction of length of the concrete at the centre of application of the compressive force multiplied by the total compressive force, *i.e.*, in case of parabolic compression.

$$U_c = \frac{1}{2} \times \frac{1}{3}\, l\, \frac{5}{8} e_c \times \frac{2}{3} f_c bkd = \frac{5}{72}\, lbkdf_c e_c \dots\dots \quad (17)$$

in which $\frac{5}{8} e_c$ is the unit compression at the centre of gravity of the parabolic area, and the factor following is the total compressive force above the neutral axis.

But since the resisting and the applied moments are equal,

$$\frac{2}{3} f_c\, bkdjd = \frac{1}{6} Wl, \text{ or } bkdf_c = \frac{Wl}{4\, jd} \quad \ldots\ldots\ldots\ldots (18)$$

Hence,

$$U_c = \frac{5\, Wl^2 e_c}{228\, jd} = 0.022\, \frac{Wl^2 e_c}{jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

Now using (8), (16) and (19) we have

$$\frac{U_c}{U} = 0.475\, \frac{k}{j}, \text{ or } \frac{3}{2}\, \frac{U_c}{U} = 0.712\, \frac{k}{j} \ldots\ldots\ldots\ldots (20)$$

In case we use $k = 0.4$ we have for parabolic compression, $U_c/U = 0.223$ as the fraction of the work stored in the concrete in the middle third. If this be increased by 50 per cent for the two end thirds we have

$$\frac{3}{2}\, \frac{U_c}{U} = 0.335 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

for the total compression in the concrete. This last estimate in (21) may be rather excessive as appears when we take the sum of (14) and (21), making a total of

$$\frac{3}{2}\, \frac{(U_s + U_c)}{U} = 0.97 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

since it would seem probable that more than 3 per cent might be lost in cracking of concrete and slipping of rods in concrete. For this case we have

$$\frac{U_s}{U_c} = 1.226 \frac{i}{k} = 1.9$$

However, (21) is somewhat modified in case we assume straight line compression, when we compute instead of (17):

$$U_c = \frac{1}{2} \times \frac{1}{3}\, l \times \frac{2}{3}\, e_c \times \frac{1}{2} f_c bkd = \frac{lbkdf_c e_c}{18} \ldots\ldots (23)$$

But by equating the resisting and applied moments we have

$$\tfrac{1}{2} f_c bkdjd = \tfrac{1}{6}\, Wl, \text{ or } b\, k\, d\, f_c = \frac{Wl}{3\, jd}$$

Hence,

$$U_c = \frac{Wl^2 e_c}{54\, jd} = 0.0185\, \frac{Wl^2 e_c}{jd} \ldots\ldots\ldots\ldots\ldots\ldots (24)$$

and

$$\frac{U_c}{U} = 0.4\, \frac{k}{\ } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

Now if $k = 0.4$, and $j = 1 - \frac{1}{3} k = 0.87$ we find $U_c/U = 0.184$, and $\frac{U_s}{U} = 0.414$, and $\frac{3}{2} \frac{U_s + U_c}{U} = 0.897$, a not improbable value.

For this case we have

$$\frac{U_s}{U_c} = 1.5 \frac{i}{k} = 2.25$$

The correct values seem probably to lie between those calculated from the hypothesis of parabolic compression and those calculated from the straight line hypothesis. The results thus arrived at indicate that 60 per cent or more of the work expended upon the beam during flexure by the downward movement of the load is stored as potential energy of elastic elongation in the steel, and that approximately half as much has been expended in the longitudinal compression of the concrete.

These results are confirmed by the results of calculations detailed in the accompanying tables, which are based on the average values of k obtained in the tests of beams of seven different steel ratios, as given in Table 26, page 60, of Paper No. 2.

Average Work in Reinforced Concrete Beams as Per Tests in Table 26, Page 60 U. S. Technological Paper No. 2.

No. of ½ inch rods	k, mean of 3 beams	$j = 1 - \frac{3}{8} k$	$\frac{3}{2} \frac{U_s}{U} = 0.9 \frac{i}{j}$	$\frac{3}{2} \frac{U_c}{U} = 0.7 \frac{k}{j}$	$\frac{3}{2} \frac{(U_s + U_c)}{U}$	$\frac{U_s}{U_c}$	$j = 1 - \frac{1}{3} k$	$\frac{3}{2} \frac{U_s}{U} = 0.9 \frac{i}{j}$	$\frac{3}{2} \frac{U_c}{U} = 0.7 \frac{k}{j}$	$\frac{3 (U_s + U_c)}{2 U}$	$\frac{U_s}{U_c}$
$f_s = 16,000$											
2	.358	.866	.667	.294	.961	2.27	.881	.656	.290	.946	2.26
3	.380	.8575	.651	.309	.960	2.16	.873	.639	.311	.950	2.05
4	.418	.843	.621	.351	.972	1.77	.861	.608	.345	.953	1.76
5	.407	.847	.630	.342	.972	1.84	.864	.618	.335	.953	1.85
6	.428	.840	.615	.363	.978	1.69	.857	.600	.356	.956	1.68
7	.443	.834	.602	.378	.979	1.59	.852	.587	.371	.958	1.58
8	.455	.829	.591	.382	.982	1.51	.848	.578	.383	.961	1.51
Mean	.413	.845	.625	.360	.975	1.81	.862	.614	.341	.955	1.81
$f_s = 32,000$											
2	.288	.892	.719	.230	.949	3.13	.908	.705	.225	.930	3.13
3	.325	.878	.692	.261	.953	2.65	.892	.681	.258	.939	2.64
4	.360	.835	.690	.306	.996	2.25	.880	.654	.291	.945	2.25
5	.359	.865	.666	.296	.962	2.25	.880	.656	.290	.946	2.26
6	.381	.857	.650	.317	.967	2.05	.873	.638	.311	.948	2.05
7	.402	.842	.641	.339	.980	1.90	.866	.621	.330	.951	1.88
8	.416	.844	.623	.351	.954	1.77	.861	.611	.345	.956	1.77
Mean	.361	.859	.669	.300	.969	2.29	.880	.652	.293	.945	2.22

4. In order to determine what part of the total work done by the load on a flat-slab floor is expended upon and stored in the slab steel reinforcement, assume that the centre of gravity of a uniformly distributed panel load W moves downward during loading through a distance equal to one-half of the total deflection D_2 of the panel centre. This estimate of a mean deflection $= \frac{1}{2}D_2$ probably exceeds the actual amount of the mean downward motion by a very small amount in case of many panels equally loaded, but is probably somewhat too small for the case of a single-loaded panel, especially for a deck slab, or one supported on columns of small stiffness, for, under such conditions the lines of inflection approach nearer to the supports, and the dish-shaped or suspended spans around the panel centres are somewhat larger in area than when all panels are loaded. This assumed value of $\frac{1}{2}D_2$ is, however, sufficiently accurate to enable us to make a satisfactory comparison of work done in slabs with that already found for beams.

The expression for the work of a load gradually applied to a panel is one-half the product of the load W, by the mean deflection $\frac{1}{2}D_2$ *i.e.*,

$$U = \tfrac{1}{4} WD_2 \ldots\ldots\ldots\ldots\ldots\ldots (26)$$

in which D_2 may be obtained by test, or usually with sufficient accuracy from equation (71) page 204, "Concrete Steel Construction," Eddy and Turner. Now making use of this value of D_2 first before we have recourse to experimental confirmation

$$U = \frac{W^2 l^3}{19 \times 10^{10} A_1 d^2} \ldots\ldots\ldots\ldots\ldots\ldots (27)$$

in which l is the span in inches, A_1 the cross section of a single belt, in case of four-way reinforcement of side and diagonal belts, and d is the depth of the centre of gravity of the steel below the top of the slab at the panel centre.

Again, U_2 the work stored in the slab rods of a panel is equal to one-half the product of the volume of steel in the rods, multiplied by the mean value of the product of unit stress f and unit strain c, *i.e.*, by the mean value of $fe = f^2/E$. Now the volume of steel in the side and diagonal belts of a square panel is

$$v = 2\,(1 + \sqrt{2})\, lA_1 = 4.83\, lA_1 \ldots\ldots\ldots\ldots\ldots (28)$$

and the mean value of f^2 in a rod is $\frac{1}{3} f_s^2$ when f_s is the maximum steel stress at mid span, provided the stress diminishes uniformly to zero at the lines of inflection. Although it does not diminish at so rapid a rate as this near its maximum value, nevertheless $\frac{1}{3} f_s^2$ is a suitable value to assume because not all the rods in a belt have stresses at mid span as large as the largest observed in either rod.

Let us assume from Equation (34), page 183, and from equation (52), page 196, "Concrete Steel Construction," that a mean maximum value at mid span is

$$f_s = \frac{Wl}{200\,A_1 d} \ldots\ldots\ldots\ldots\ldots\ldots (29)$$

Then the work stored in the slab rods of a panel is

$$U_2 = \tfrac{1}{2} v \times \tfrac{1}{3} \frac{f_s^2}{E} = \frac{4.83\, l\, A_1}{6 \times 3 \times 10^7} \left(\frac{W\, l}{200\, d\, A_1} \right)^2 \ldots\ldots (30)$$

Hence by (26) and (30)

$$\frac{U_2}{U} = 0.127 = \tfrac{1}{8} \text{ nearly} \ldots\ldots\ldots\ldots\ldots\ldots (31)$$

By (26), (28) and (30) this ratio may also be found otherwise in terms of observed quantities, without assuming (29) as follows:

$$\frac{U_2}{U} = \frac{1.07\ 1\ A_1 f_s}{10^7\ W\ D_2} \ldots\ldots\ldots\ldots\ldots\ldots (32)$$

which may therefore be used to calculate the proportion of the total work of deflection stored in the steel from test data alone and independently of theory, since it depends on observed quantities only.

For example, in the test of the Deere and Webber Building* assuming a mean observed value of $f_s = 9000$ at mid span

$$\frac{U_2}{U} = \frac{1.07 \times 226 \times 12 \times 0.15\ (9\ 000)^2}{107 \times 124\ 678 \times 0.224} = 0.126$$

Similarly in the test of the Northwestern Glass Company Building† $U_2/U = 0.121$, and in the St. Paul Bread Company Building‡ $U_2/U = 0.128$. These results of tests differ very little from the theoretical value obtained above in (31). They show con-

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[*] See "Concrete-Steel Construction," page 228.

[†] Page. 227.

[‡] Page 232.

clusively that a much smaller proportion of the total work of the load is stored in the reinforcing rods of a slab than in those of a beam, in fact under test conditions only about one-fifth as much.

This difference is so large as to make it certain that beam theory is entirely inapplicable to flat slabs, as it evidently should be when we consider the physical and mechanical dissimilarity of the two structures, one of the most noticeable of which is the almost total loss of resistance of concrete in the tensile regions of beams under heavy load, as shown by the numerous cracks below the neutral axis already referred to, while ordinary tests of slabs show little if any cracking that would materially reduce the resistance of the concrete in opposing the very complicated stresses to which the concrete is subjected in the tensile zones of the panel, to all of which the concrete opposes an effective resistance, as is evident from the fact that it continues intact. The dissemination of the steel in a fine-grained structure throughout these zones enables it to bring all the concrete into action in such a way as to afford the resistance needed to effect a result such as is impossible in beams, since in the tensile zones of slabs it is subjected to a combination of several compressions, twists and shears, which it is abundantly able to bear; and it must be remembered, in this connection, that any kind of resistance called into play in such a structure assists by just so much in transmitting the load to the supports. The concrete in a slab, without being taxed beyond its direct tensile resistance, as it is taxed in beams, is able to afford at the same time other effective resistances that relieve the steel and greatly enhance the load carrying capacity of the slab.

If only about $\frac{1}{8}U$ is stored in the slab steel, where, it may be asked, is the remaining $\frac{7}{8}U$ to be found? Most of it must be found somewhere in the concrete, which is subjected to various kinds of stress not found in beams. In fact, the numerous observable and microscopic cracks in beams almost entirely prevent any storage of energy in the concrete, except that of compression, and a small amount in vertical and horizontal shear, while the almost total absence of cracks in slabs permits the storage of more energy in shears than in beams, and permits the storage of energy in the slab in twisting and in several other ways, as well as in bond shear deformations throughout the tensile zones of the slab.

The enormous difference which we have found above between the storage of energy in beams and slabs thus proves conclusively that the mode of action of slabs is entirely different from that of beams, and that their analysis must also be entirely different. It is consequently wholly inadmissible to attempt to compute slabs by beam theory.

5. *Summary.*—Uniformly reinforced concrete beams loaded at the one-third points store some 60 per cent. or more of the total energy of flexure in the steel reinforcement alone, and only about half as much in longitudinal compression in the concrete.

Uniformly loaded flat slab floors with four-way reinforcement store only about 12.5 per cent. of the total energy of flexure in the slab steel. Since this is only about one-fifth of the amount stored in beams, it evidently is impossible to compute slabs by beam theory.

Asbestos Production. J. S. DILLER. (*U. S. Geological Survey.*)—The asbestos industry of the United States is in better condition now than ever before, especially as to the quantity and the grade produced, and the outlook is encouraging. Most of the asbestos used in the large asbestos factories of the United States comes from Canada, but the growing appreciation of the high quality American fibre, especially that from Arizona, is a welcome feature of the industry.

The total quantity of domestic asbestos sold in 1917 was 1683 short tons, valued at $506,056, an increase of about 13 per cent. in both quantity and value over 1916. Most of the domestic asbestos comes from Arizona, where the proportion of crude spinning fibre to that of lower grades is much larger than in Canada, so that the average price of American fibre in 1917 was $301 a ton, whereas the average price of that in Canada was only about $50.

Some years ago the opinion was expressed that as the Arizona fibre contains less iron than that mined in Canada it is therefore better adapted to use for electrical insulation than the Canadian fibre.

A small amount of spinning fibre was mined in Fremont County, Wyo., from a contact deposit of remarkable interest.

The increased demands for asbestos due to the war have been met largely by increased imports from Canada. The imports of asbestos from South Africa and Italy have been largely cut off. The demand for imported asbestos for use in filters is being supplied by amphibole asbestos obtained from residual deposits of the crystalline rocks of Maryland.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

The heliotropine affected the plants markedly from the beginning. The concentration used proved very harmful, and the plants in the entire set of solution made only a small growth. Both tops and roots were injured. The tops, however, seemed more affected than the roots.

The green weights of each set of cultures are given in the diagrams of Fig. 23.

An examination of the two diagrams shows the green weight of each culture in the heliotropine set to be much smaller than the corresponding culture in the set without heliotropine. The total weight of all the cultures in the normal set was 185.4 grammes, and that of the heliotropine set 69.3 grammes. This is a reduction of 62 per cent. in growth. The 21 solutions in the phosphate end of the triangle produced 50.3 grammes green weight in the set without heliotropine and only 17.5 grammes in the set with heliotropine, a reduction of 65 per cent. The 21 cultures in the nitrate end of the triangle produced 52.7 grammes green weight in the normal set and 23.0 grammes in the heliotropine set, a reduction of 61 per cent., and the same number of cultures at the potash end of the triangle produced 54.4 grammes green weight in the normal cultures and 25 grammes in the treated set, which is a reduction of 54 per cent. This indicates that heliotropine may be less harmful in solutions containing high proportions of potassium. The injury to the plants over the entire triangle was so great, however, that conclusions should not be drawn. The absorption of salts by the plants is not in harmony with the more normal growth in the high potash solution.

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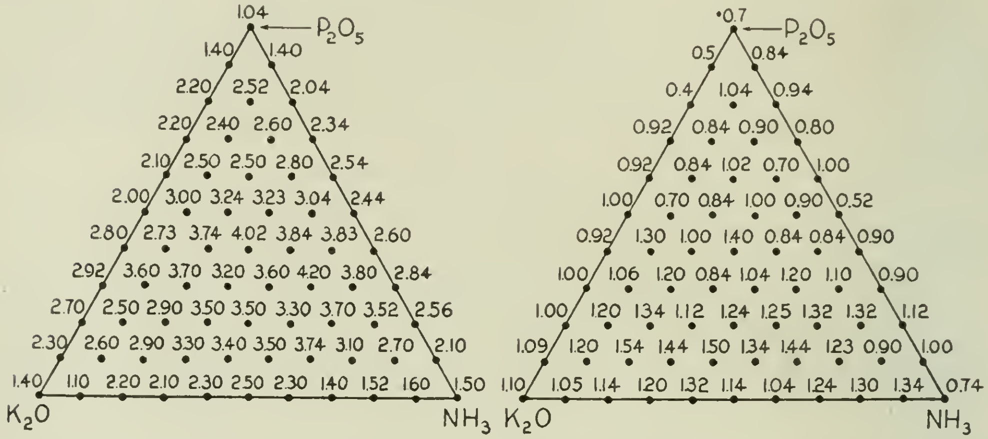
* Continued from page 316, Vol. 186, September, 1918.

Absorption of Nutrient Salts.

The total absorption of P_2O_5, nitrates stated as NH_2, and K_2O for all the cultures of the normal triangle was 1726.7 milligrammes and only 668.0 milligrammes for the cultures of the heliotropine set.

Phosphates.—The plants in the normal set absorbed 446.3 milligrammes of P_2O_5, while the plants of the heliotropine set absorbed 163.0 milligrammes, 283.3 milligrammes less, a reduction of 64 per cent.

FIG. 23.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate and potash: (1) Without heliotropine and (2) with 25 ppm. heliotropine.

Nitrates.—The normal cultures absorbed 620.1 milligrammes of nitrates stated as NH_3, and the heliotropine cultures 277.4 milligrammes, 342.7 milligrammes less, or a reduction of 56 per cent.

Potash.—The absorption of potash was 660.2 milligrammes of K_2O by the normal cultures and 227.6 milligrammes by the heliotropine cultures, 432.6 milligrammes less. This is a reduction of 66 per cent.

The nitrate absorption seems to have been the least interfered with by the presence of heliotropine, yet the plants made a more normal growth in the high potash solutions. The absorption of each of the nutrient salts was greatly interfered with, as well as the growth of the plants.

FORMALDEHYDE.

Formaldehyde, HCOH, is a powerful disinfectant, either as a gas or in solution. It is formed from methyl alcohol by oxidation. The action of formaldehyde in plants is interesting on account of the well-known assumption of Beyer's (5); namely, the production of formaldehyde in plants through the interaction of carbon dioxide and water, and the subsequent polymerization of this to a sugar. It was also suggested by Erlenmeyer (17) that carbonic acid is acted on by water under conditions existing in the plant with the production of formic acid and hydrogen peroxide. The formaldehyde would then result from the reduction of formic acid. Numerous investigations attempting the formation of formaldehyde directly from carbonic acid and water have been reported. Lob (28) claims its formation by substituting sunlight by a silent electric discharge, and in this way it shows that formaldehyde is a direct reduction product of CO_2 and H_2O, and Fenton (19) claims to have accomplished its formation directly from carbonic acid by passing a current of carbon dioxide through pure water in contact with several rods of amalgamated magnesium.

As a result of Beyer's hypothesis attempts have been made to detect formaldehyde in plants of various species and grown under various conditions. This has been difficult, for if formaldehyde exists in plants it can be present only in minute quantities on account of its great toxicity. Usher and Priestley (77) claim to have definitely proved its presence in dead plants. Most investigators assume its presence in living plants, but are unable to demonstrate this on account of lack of sensitiveness of methods to detect such minute quantities as must exist in plants. Angelico and Catalano (1), by means of the active glucoside principle of *Atractylis gummifora*, detected formaldehyde in the juices of green plants of many species.

Effect on Growth.

A great many experiments have been made on the assimilation of formaldehyde by plants. The first extensive investigation was made by Bokorny (6), who attempted to grow water plants in diluted solutions. In concentration of 20 parts per million the plants were killed. Methylal, which decomposes into formaldehyde, giving up extremely small amounts, stimulated the growth of *Spirogyra* and produced starch in the absence of carbon dioxide. It was also shown that water-cress assimilated formaldehyde vapor in the absence of both oxygen and light (7).

Formaldehyde in air free from carbon dioxide produced a stimulation of *Phaseolus vulgaris,* as shown by Grafe and Vieser (23). Bouilloc and Guistiniana (8) succeeded in growing white mustard in solutions containing traces of formaldehyde; they report a stimulation when the plants were grown in the light. Elodea were grown successfully in solutions containing 10 parts per million of formaldehyde (9). Baker (3), who also studied the effect of formaldehyde vapor on the growth of white mustard, found that the plants could use the aldehyde for synthesis of food material to some extent in the light. There was considerable gain in dry weight of the plant under the influence of the aldehyde. The poisonous effect with the higher concentrations was more intense in darkness than in light. Among other experiments recorded, Clark (15) reports that formaldehyde is very toxic to fungi, being fatal to several species in $\frac{N}{2048}$ solutions. A distinct injury was exhibited in $\frac{N}{4096}$ solutions, but all the fungi tested produced normal development in a $\frac{N}{131072}$ solution. No stimulation is reported.

Effect in Nutrient Solutions with Various Fertilizer Salts.

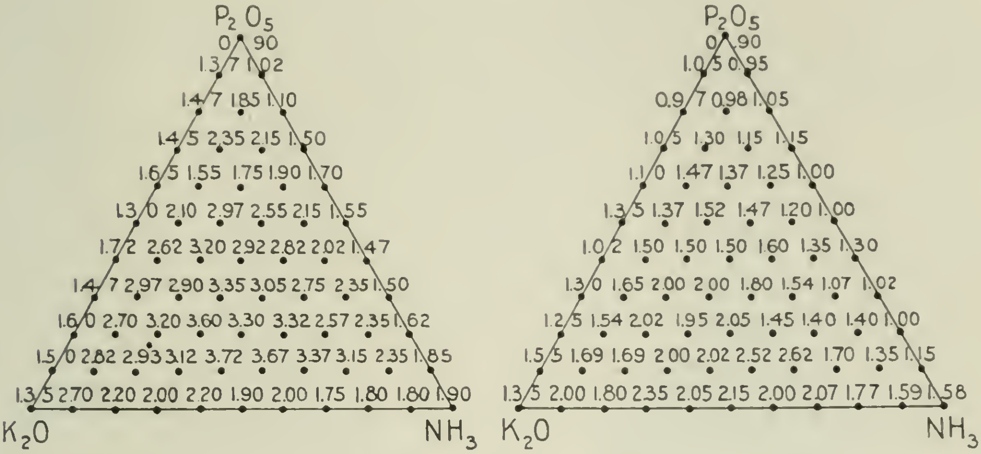
In the experiments recorded in this paper with formaldehyde in nutrient solutions the complete triangular set was used. The formaldehyde was used in concentrations of 20 parts per million. Wheat plants grew in these solutions from March 31 to April 12, 1915. As in the former experiments with the other aldehydes, four changes of solutions were made. The solutions were analyzed to determine the amount of nutrients absorbed.

The green weight of the wheat plants of each solution without and with formaldehyde are given in diagrams of Fig. 24.

The results of the experiment are in harmony with those of former investigations. The aldehyde reduced growth very much. In most of the cultures the green weight is less in the formaldehyde solution than in the corresponding culture without formaldehyde. The total green weight of all the cultures of the normal set was 149.8 grammes, against 104.3 grammes for all the cultures in the formaldehyde set. The formaldehyde at the concentration used reduced growth 30 per cent.

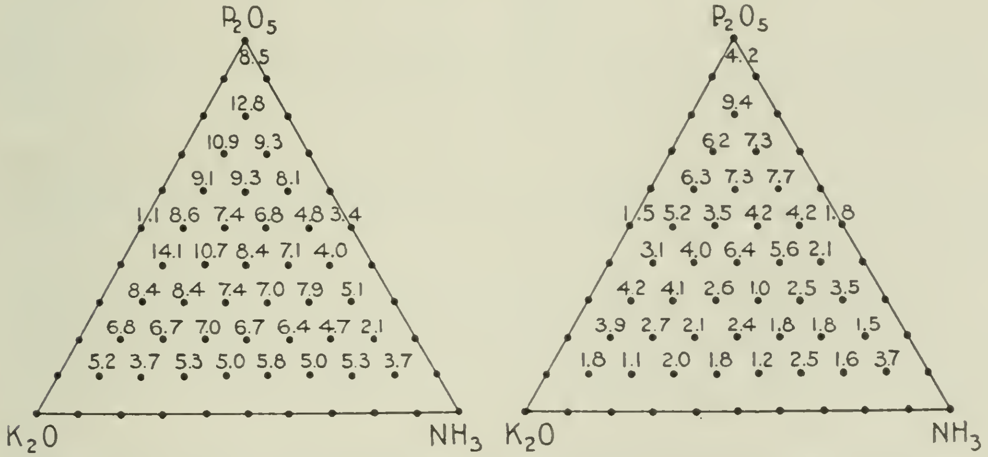
When the cultures are considered from the point of view of the composition of the solution, it is seen there were practically no differences in the harmfulness of formaldehyde in the different sections of the triangle. In the mainly phosphatic cultures growth was reduced 32 per cent., in the mainly nitrogenous 30 per cent., and in the mainly potassic 31 per cent.

FIG. 24.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without formaldehyde and (2) with 20 ppm. formaldehyde.

FIG. 25.



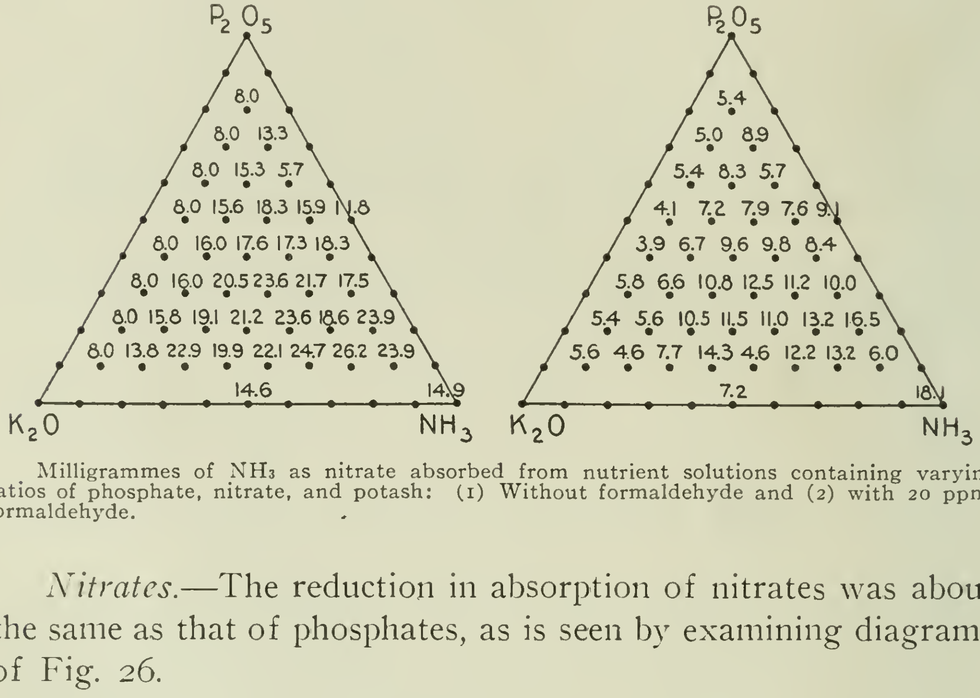
Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without formaldehyde and (2) with 20 ppm. formaldehyde.

Absorption of Nutrient Salts.

Phosphates.—The absorption of all salts was also much less in the cultures with formaldehyde. The amounts of P_2O_5 removed by the plants in each culture are given in diagrams of Fig. 25.

The normal set of cultures absorbed 265.0 milligrammes of P_2O_5, and the set of cultures containing formaldehyde 140.3 milligrammes, a reduction of 47 per cent.

FIG. 26.



Milligrammes of NH_3 as nitrate absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without formaldehyde and (2) with 20 ppm. formaldehyde.

Nitrates.—The reduction in absorption of nitrates was about the same as that of phosphates, as is seen by examining diagrams of Fig. 26.

The total amount of nitrates absorbed by the normal cultures was 621.6 milligrammes of nitrates stated as NH, and the absorption by the aldehyde cultures was 337.1 milligrammes, a reduction of 46 per cent.

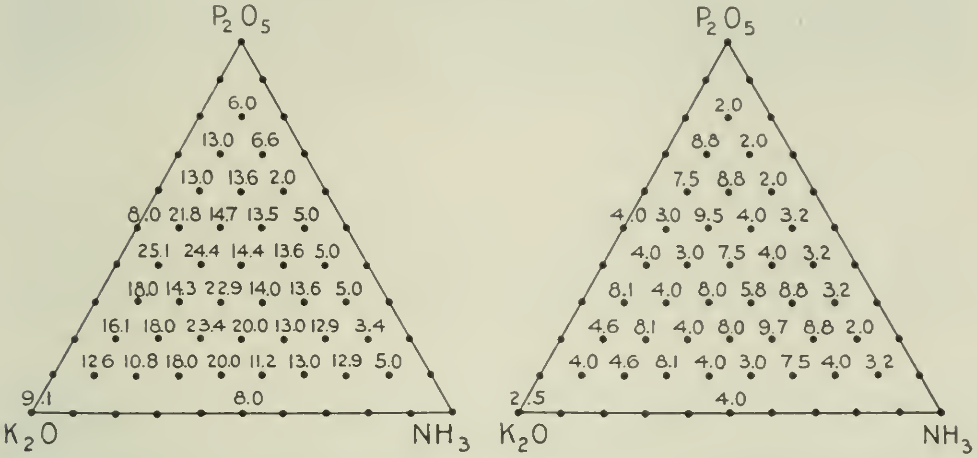
Potassium.—The absorption of potash was interfered with more by the presence of formaldehyde than were phosphates or nitrates. The total amount of K_2O removed by the normal cultures was 415.4 milligrammes, against 204.5 milligrammes for the set of cultures containing formaldehyde. This is a reduction of 60 per cent. The detail figures are given in diagrams of Fig. 27.

PARAFORMALDEHYDE.

Effect in Solutions with Various Fertilizer Ingredients.

Paraformaldehyde, $\frac{\mathrm{HCOH}}{\mathrm{HCOH}}$, is a polymeric variety of formaldehyde. It is a solid substance, and is formed when a water solution of formaldehyde is evaporated. So far as the author is aware, its effects on plant growth had not before been determined. In the experiments reported below it proved to be fully as harmful as formaldehyde. In 25 parts per million in nutrient-culture solutions it materially injured growth, and in solutions of 50 parts per million it was extremely harmful.

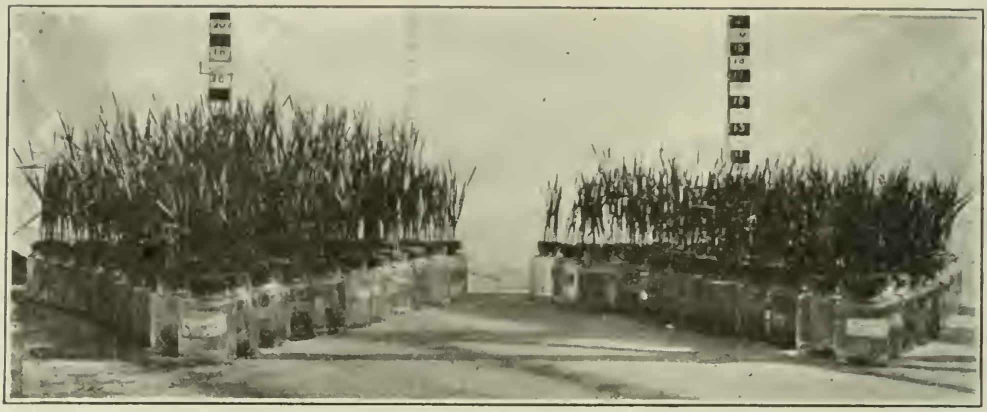
FIG. 27.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate nitrate, and potash: (1) Without formaldehyde and (2) with 20 ppm. formaldehyde.

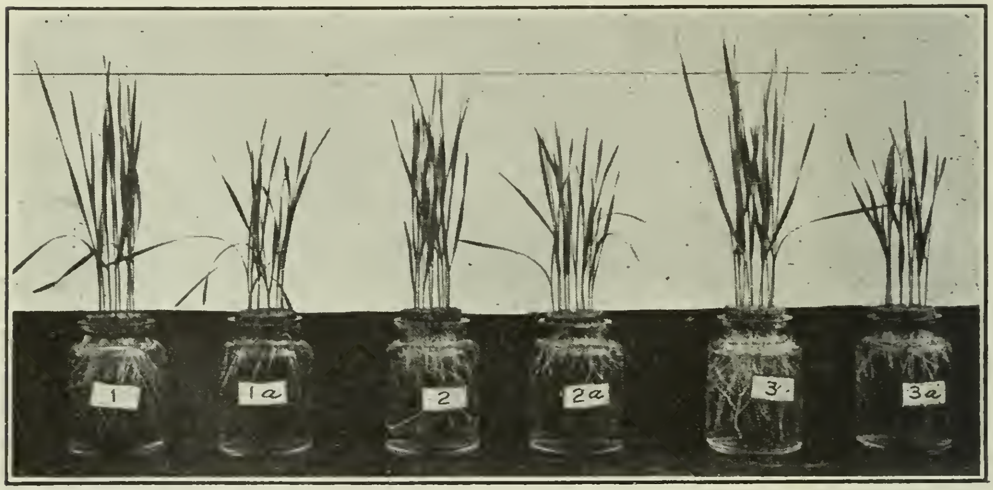
As in the experiments with the other aldehydes reported, wheat plants were grown in a complete set of nutrient solutions, without and with the paraformaldehyde. The solutions were prepared according to the triangular schemes, there being 66 in each set. The plants grew from January 27 to February 8, 1917. The solutions were changed four times during the experiment. The paraformaldehyde was used in this test in amounts of 25 parts per million. Photographs were taken when the plants were ten days old. In Fig. 28 the two sets of cultures are shown in triangular form. The triangle on the left is the normal solutions—that is, the set without paraformaldehyde—and the triangle on the right is the set containing 25 parts per million paraformaldehyde. The difference in growth as shown in the plate between the two sets of plants is very marked. A near view of three of the cultures is shown in Fig. 29. Cultures 1 and 1*a* are duplicate solutions, containing 48 ppm. P_2O_5, 16 ppm. NH_3 as nitrate, and 10 ppm. K_2O. Culture 1*a* contains the paraformaldehyde. Likewise cultures 2 and 2*a* are duplicate solutions, containing 16 ppm. P_2O_5, 48 ppm. NH_3 as nitrate, and 16 ppm. K_2O; culture 2*a* contains paraformaldehyde. Cultures 3 and 3*a* are also duplicates, containing 16 ppm. P_2O_5, 16 ppm. NH_3 as nitrate, and 48 parts per million K_2O. Culture 3*a* contains the paraformaldehyde. Here it is seen that the aldehyde had affected root

Fig. 28.



Wheat in nutrient solutions of various ratios without and with paraformaldehyde: Triangle on left, nutrient solutions without paraformaldehyde; triangle on right, nutrient solutions with 25 ppm. paraformaldehyde.

Fig. 29.

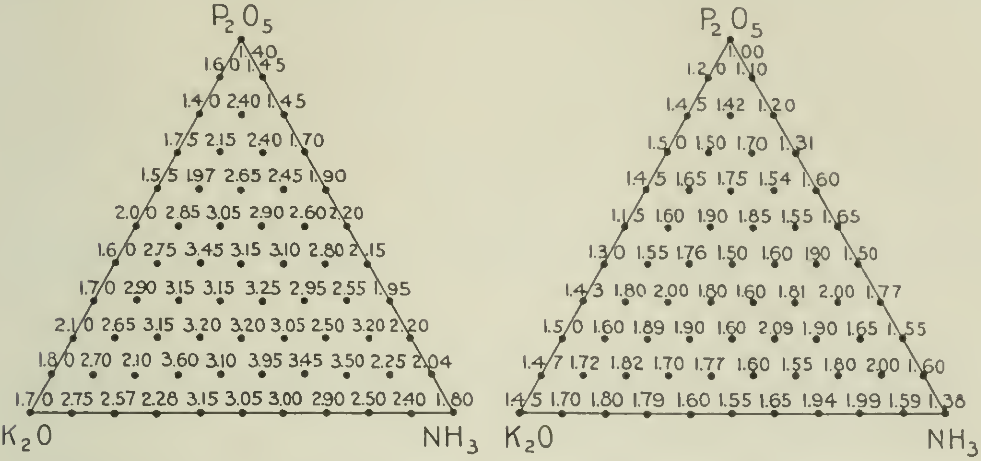


Nutrient solutions without and with paraformaldehyde: No. 1 and 1*a*, solution containing 48 ppm. P_2O_5, 16 ppm. NH_3, and 10 ppm. K_2O,; No. 2 and 2*a*, containing 16 ppm. P_2O_5, 48 ppm. NH_3, and 16 ppm. K_2O,; No. 3 and 3*a*, solution containing 16 ppm. P_2O_5, 16 ppm. NH_3, and 48 ppm. K_2O. Bottles marked "a" contain 25 ppm. paraformaldehyde.

growth as well as top growth in each of the solutions, regardless of its composition. In the diagrams of Fig. 30 are given the green weights of the plants in the normal set of solutions and in the paraformaldehyde set.

The growth in each solution containing paraformaldehyde is smaller than in the corresponding solution without it. The total growth of the 66 normal cultures was 165.7 grammes, and that of the paraformaldehyde set 107.2 grammes. This is a reduction of 35 per cent. in growth.

FIG. 30.



Green weight in grammes of wheat plants in nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without paraformaldehyde and (2) with 25 ppm. paraformaldehyde.

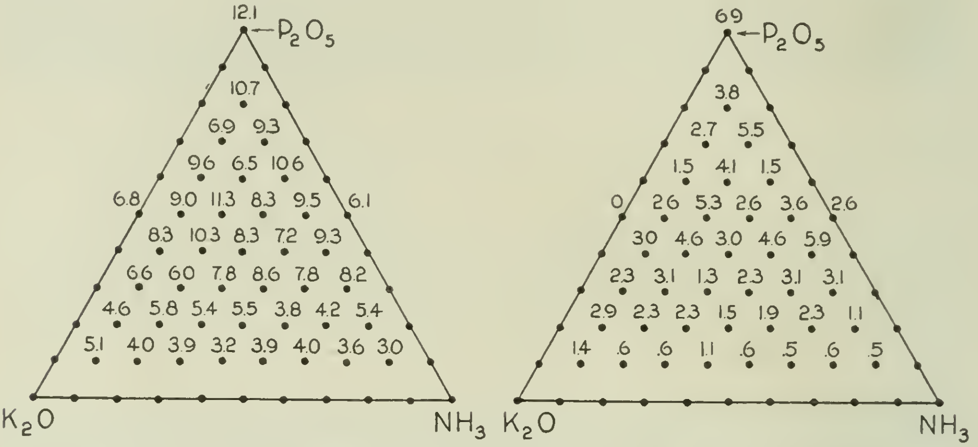
When the cultures are considered from the point of view of their composition, it is seen that growth was more normal in solutions in the phosphate end of the triangle. Referring again to Fig. 5, the cultures in sub-triangle 1–16–21—that is, the 21 mainly phosphatic solutions—produced 43.8 grammes green matter in the normal set and 31.1 grammes in the paraformaldehyde set, a reduction of 30 per cent. The 21 mainly nitrogenous cultures (sub-triangle 21–61–66) produced 55.9 grammes green matter in the normal set and 36.3 grammes in the aldehyde set, a reduction of 35 per cent. The 21 mainly potassic solutions (sub-triangle 16–56–16) produced 54.0 grammes and the aldehyde solutions 34.5 grammes, a reduction of 37 per cent.

Another experiment using the complete set of nutrient solution without and with paraformaldehyde was made in which the aldehyde was used in amounts of 50 parts per million. This proved very harmful to the plants. Growth was reduced 58 per cent. as an average of the entire set. In this experiment growth was also more normal in the mainly phosphatic cultures. So the results as to its relative harmfulness in nutrient solutions of different compositions do not seem merely accidental. It is rather markedly indicated that phosphates ameliorate its harmful effect.

Absorption of Nutrient Salts.

Phosphates.—The absorption of salts was greatly decreased by the action of paraformaldehyde. The amount of P_2O_5 in milligrammes absorbed from the cultures analyzed in each set

FIG. 31.



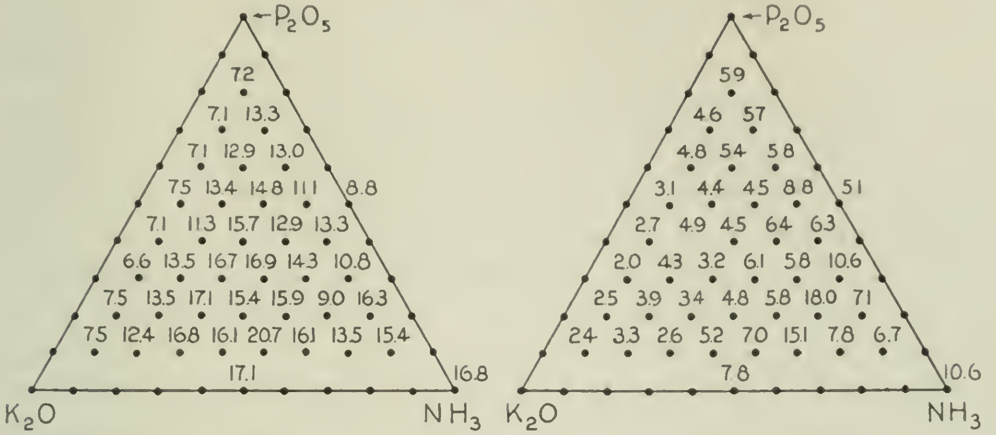
Milligrammes of P_2O_5 absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without paraformaldehyde and (2) with 25 ppm. paraformaldehyde.

are given in the diagrams of Fig. 31. The normal set of cultures absorbed 270.8 milligrammes and the paraformaldehyde set only 99.4 milligrammes. The absorption of P_2O_5 was reduced 63 per cent.

Nitrates.—The absorption of nitrates was not lessened quite so much as were the phosphates. The amount absorbed from each solution can be seen by examining the diagrams of Fig. 32. The normal set of cultures removed from the solutions 602.8 milligrammes of NH_3 as nitrates, and the paraformaldehyde set only 238.0 milligrammes. This is a reduction of 63 per cent. in the amount of nitrate absorbed.

Potash.—The decrease in the amount of K_2O removed was even greater than the phosphates or nitrates. The detail figures showing the removal of K_2O from each set of solutions are given in diagrams of Fig. 33. The total amount of K_2O in milligrammes removed from the solutions in the normal set was 531.8 and from the aldehyde set 177.8, a reduction of 67 per cent.

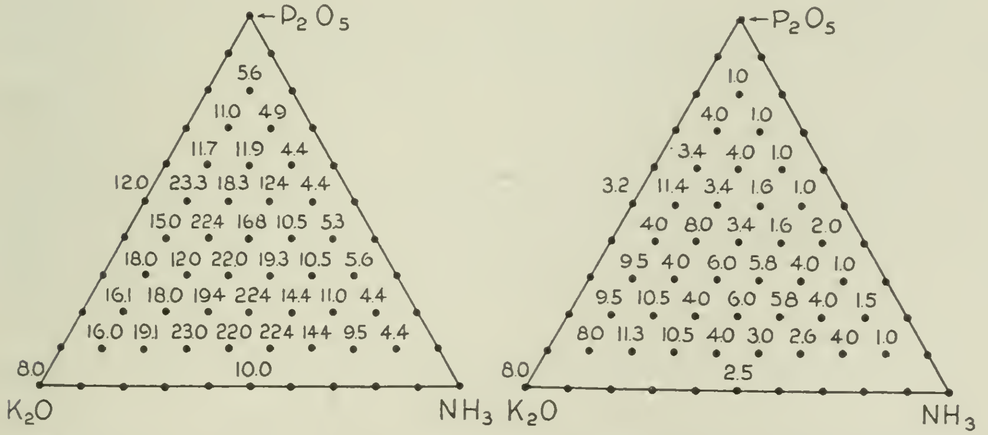
FIG. 32.



Milligrammes of NH_3 as nitrate absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without paraformaldehyde and (2) with 25 ppm. paraformaldehyde.

Although growth was more normal in the mainly phosphatic solutions, showing that there was some action by the phosphates which changed the physiological effect of paraformaldehyde, the absorption of nitrates by plants growing in the presence of this aldehyde was more normal than the absorption of phosphates or of potash.

FIG. 33.



Milligrammes of K_2O absorbed from nutrient solutions containing varying ratios of phosphate, nitrate, and potash: (1) Without paraformaldehyde and (2) with 25 ppm. paraformaldehyde.

SUMMARY OF THE EXPERIMENTS ON THE EFFECT OF ALDEHYDES ON GROWTH IN CULTURE SOLUTIONS.

The effects of six different aldehydes on the growth of plants in distilled water and in nutrient culture solutions were determined. The culture solutions were composed of calcium acid phosphate, sodium nitrate, and potassium sulphate. Some solutions contained the salts singly, some in combinations of two and others in combinations of the three salts, the proportion varying in 10 per cent. stages. The aldehydes were found to affect growth differently in solutions composed of the different fertilizer constituents. Each of the aldehydes studied—namely, salicylic aldehyde, vanillin, benzaldehyde, heliotropine, formaldehyde, and paraformaldehyde—was harmful in aqueous solutions in comparatively small amounts.

Salicylic aldehyde, used in amounts of 10 parts per million, reduced growth in the set of 66 nutrient solution 27 per cent. It was least harmful in those solutions containing a high percentage of phosphate, and its harmfulness was somewhat lessened in the solutions in the presence of calcium carbonate. There was a more nearly normal absorption of phosphate than of nitrates or potash under the influence of salicylic aldehyde. This is in harmony with the relatively lessened toxicity of the aldehyde in the mainly phosphatic nutrient solutions.

Vanillin was less harmful than salicylic aldehyde; it affected the roots more severely than the tops of the plants. In the complete set of nutrient solutions, the vanillin, in amounts of 50 parts per million, reduced growth 26 per cent. The reduction in growth by vanillin was virtually the same as that by the salicylic aldehyde, the vanillin being used in concentrations of 50 parts per million and the salicylic aldehyde in amounts of 10 parts per million. The harmfulness of vanillin was much less in solutions high in nitrate contents than in solutions high in phosphate or potash contents. Nitrates stimulate oxidation processes in plants and solutions which act upon the vanillin, changing or destroying it so that it is no longer harmful to plants.

Benzaldehyde, in concentrations of 25 parts per million, in the total number of nutrient solutions used in the experiment, reduced growth 30 per cent. Growth in the benzaldehyde solutions was slightly more normal in the phosphatic and potassic than in the nitrogenous solutions, and the absorption of potash was slightly more normal than the absorption of either phosphates or nitrates.

Heliotropine proved to be extremely harmful in concentrations of 25 parts per million, reducing growth 62 per cent. as an average of all the cultures. The plants were so severely injured that it was difficult to differentiate between its effects in the different solutions.

The well-known effects of formaldehyde were again demonstrated. Growth was reduced in the nutrient solution 30 per cent. when the aldehyde was used in concentrations of 20 parts per million. It was equally harmful in the different solutions, regardless of their compositions in nutrient salts. Paraformaldehyde also proved to be harmful; in 25 parts per million it reduced the growth of wheat plants in the various nutrient solutions 35 per cent., and in concentrations of 50 parts per million it severely injured the plants. It was less harmful in the solutions containing principally phosphates. It is markedly indicated that phosphates have an ameliorating action on its effect.

In the following sections the results of pot and field studies are presented. In these experiments only salicylic aldehyde and vanillin, the two aldehydes which have been encountered frequently in soils, were used.

POT EXPERIMENTS ON THE EFFECT OF VANILLIN AND SALICYLIC ALDEHYDE IN DIFFERENT SOILS.

The next step in the study of the action of aldehyde was to test the effect of these compounds when added to the soil. This part of the investigation involved experiments with a number of different plants and a number of different soils.

Effect of Varying Amounts of Salicylic Aldehyde.

The first experiment with salicylic aldehyde was with a heavy clay soil and wheat was grown. Paraffin pots (22) holding approximately one pound of soil were used, and six plants were grown in each pot. Before potting, portions of the soil were treated with varying amounts of salicylic aldehyde. The experiment was begun May 27 and discontinued June 18. The appearance of the plants near the end of the experiment is shown in

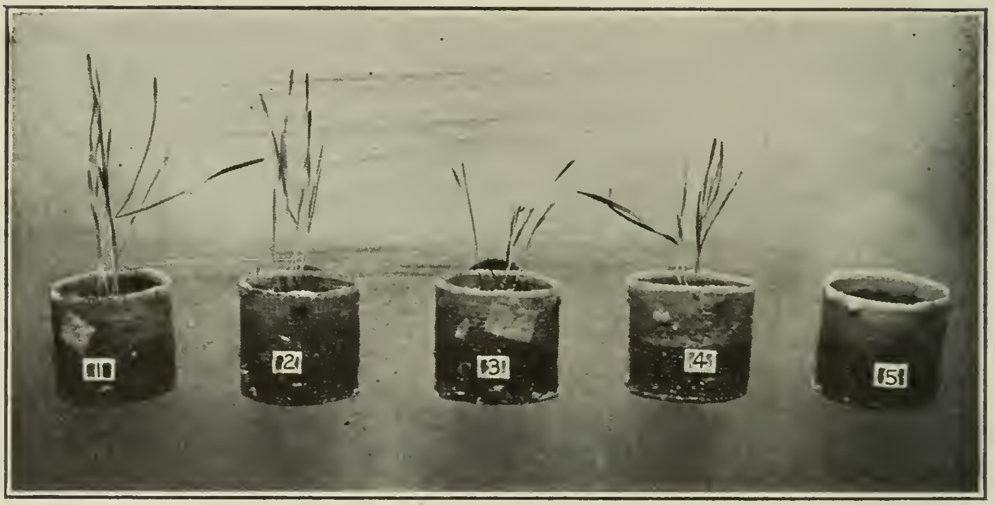
Fig. 34, and here it is clearly seen that the aldehyde is very harmful. The results are given in Table X.

TABLE X.

Effect of Salicylic Aldehyde on Wheat Plants in Soil.

No.	Treatment	Green weights grammes	Relative growth
1	Clay loam untreated	0.65	100
2	Same + 10 ppm. salicylic aldehyde	0.65	100
3	Same + 25 ppm. salicylic aldehyde	0.50	77
4	Same + 50 ppm. salicylic aldehyde	0.40	61
5	Same + 100 ppm. salicylic aldehyde	dead	...
6	Same + 200 ppm. salicylic aldehyde	dead	...

FIG. 34.



Effect of different concentrations of salicylic aldehyde on wheat: No. 1, soil untreated; No. 2 salicylic aldehyde, 10 ppm.; No. 3, 25 ppm.; No. 4, 50 ppm.; No. 5 ,100 ppm.

The weights in the table show that 10 parts per million of salicylic aldehyde in this soil had no effect, while larger amounts were quite harmful. With 25 parts per million, growth was reduced from 100 to 77, or 23 per cent.; with 50 parts per million the growth was reduced from 100 to 61, or 39 per cent. Where 100 and 200 parts per million were used the plants were killed. This experiment gives some idea as to the concentration of salicylic aldehyde that plants can stand in a soil of this kind.

The action of the aldehyde in soil and in sand was tested as to its effect on corn. The aldehyde was added to a clay soil and to a pure quartz sand in amounts of 50 parts per million. It proved very harmful.

The corn in the sand showed more harmful effect than in the clay soil. The plants grew in the small pots for one month. The salicylic aldehyde reduced growth in the clay soil 24 per cent. and in the sand 60 per cent. That the harmfulness was more marked in the sand than in the clay is probably due to the absorptive power of the clay being far greater than that of the sand, and perhaps, also, to the higher nutritive value of the soil in comparison with the pure sand.

An experiment with clover grown in a clay soil in an earthenware pot holding six pounds of soil should also be recorded here. In this test the aldehyde was added periodically during the time of the experiment. The total amount added was 100 parts per million. The clover grew from April 12 to June 21, 1912. The treated pot showed not only a poorer growth, but also a much faded color, and had a decidedly unhealthy appearance. The green weights taken at the termination of the experiment were 8.5 grammes from the control pot and only 4.2 grammes from the salicylic aldehyde-treated pot, a decrease of approximately 50 per cent. From the three experiments recorded above it is shown that salicylic aldehyde is harmful in soil and sand to wheat, corn, and clover in comparatively small amounts.

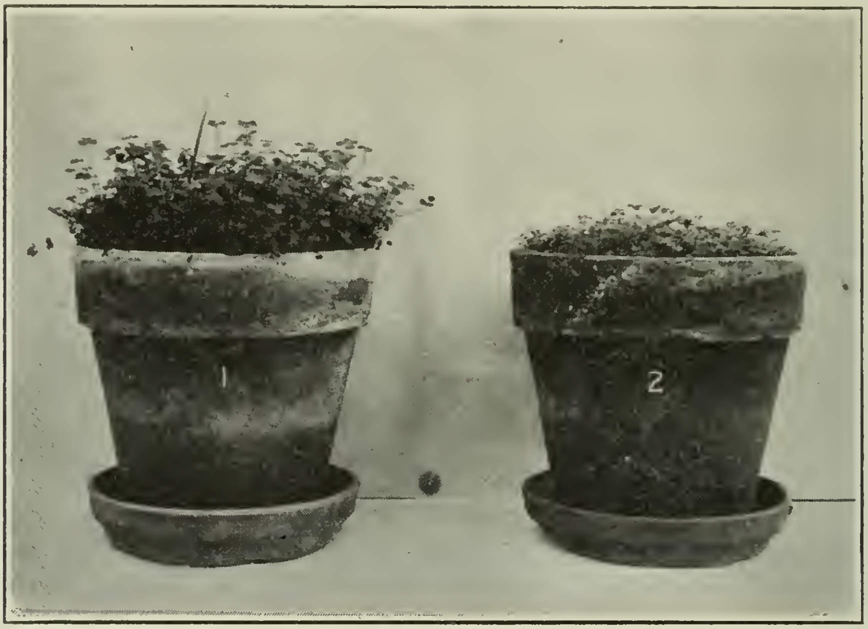
Effect of Varying Amounts of Vanillin.

Several experiments showing the effect of vanillin in soil in pots were reported in 1915 (68). Vanillin proved harmful in some of these soils, while in others it had no effect. To clover grown in Chester loam soil it was very harmful. The clover was grown in earthenware flower pots holding six pounds of soil. A total of 300 parts per million of vanillin was added to the treated pot.

When the soil was potted and planted April 28, 100 parts per million of vanillin was added, on May 15 another 50 parts per million was added, and on June 1 and 10, 50 parts per million was added. The experiment was discontinued June 21, 1912. The effect of the vanillin was noticeable from the first. The vanillin-treated plants were healthy in appearance but stunted in growth. The untreated and treated pots are shown in Fig. 35. The green weight taken at the termination of the experiment was 8 grammes for the untreated pot and only 3.8 grammes from the vanillin-treated pot, a decrease of 53 per cent.

The soil used in this experiment was a soil of moderate productiveness, and vanillin applied to it at different periods of growth of the plants was distinctly harmful. Other experiments were made to test the effect of different amounts of vanillin in several soils, each having different properties and being of different geological origin. In the following experiments wheat was used as the test crop, and the total application of vanillin was made before the soil was potted and seeds planted.

FIG. 35.



Effect of vanillin on clover: No. 1 untreated; No. 2, vanillin.

The soils used were infertile sand from Florida, an infertile sample of Susquehanna sandy loam, and a good sample of Hagerstown loam. The paraffined wire pot method was used; six wheat plants were grown in each pot, and two pots were used for each treatment. The plants grew from May 5 to May 24. Photographs of the growing plants were taken, which show the action of vanillin in each soil. At the end of the experiment the green weight was determined.

The Florida sand used in this experiment had grown citrus fruits in the field and was unproductive. A laboratory examination showed the soil to be acid. Vanillin was isolated from this soil in the investigations referred to above. The Susquehanna sandy loam was taken from an infertile area in Maryland. The natural growth on this soil was poor, and its response to fertilizer and cultural treatments was only moderate. Its oxidizing power and life activities were found to be very weak. The Hagerstown loam is a fertile soil. The soil was taken from a productive field of the Pennsylvania Agricultural Experiment Station. The soil is neutral in reaction, has strong oxidizing power, and grows thrifty plants in pots.

Vanillin was used in amounts of 100 to 500 parts per million. It was applied to the soil by dissolving in water and mixing the solution in the soil before potting. The results of the experiment on the effect of vanillin in the Florida sand, Susquehanna sandy loam, and Hagerstown loam are given in Table XI. The actual green weights of the plants grown in the two pots are given for each treatment, and the relative weight with the growth in the untreated soil taken as 100.

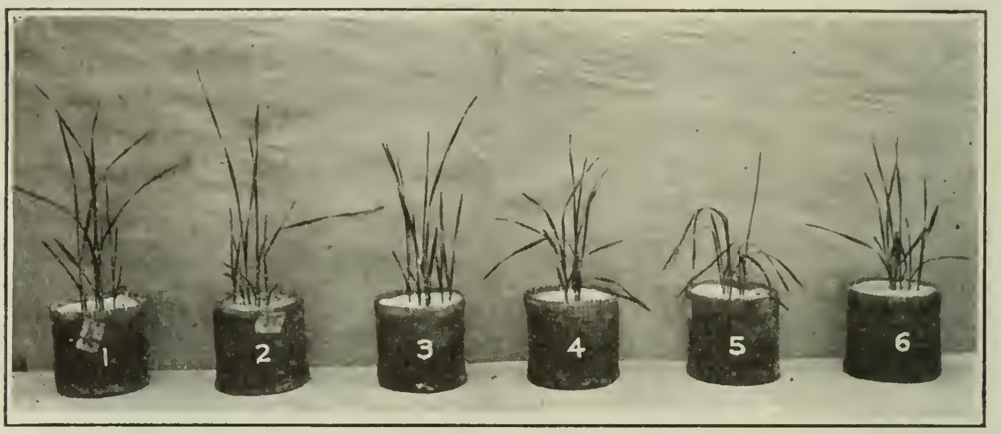
TABLE XI.

Effect of Vanillin on Wheat Plants in Pots Grown in Florida Sand, Susquehanna Sandy Loam, and in Hagerstown Loam.

Treatment	Florida yellow sand (infertile sand)		Susquehanna sandy loam (unproductive soil)		Hagerstown loam (productive soil)	
	Green weight	Relative weight	Green weight	Relative weight	Green weight	Relative weight
	Grammes		*Grammes*		*Grammes*	
Soil untreated	1.40	100	1.80	100	1.98	100
Soil + 100 ppm. vanillin	1.32	94	1.85	103	1.87	94
Soil + 200 ppm. vanillin	1.32	94	1.70	94	2.02	102
Soil + 300 ppm. vanillin	1.35	98	1.33	74	2.05	103
Soil + 400 ppm. vanillin	1.20	86	1.30	72	1.96	99
Soil + 500 ppm. vanillin	1.18	84	1.02	57	1.95	99

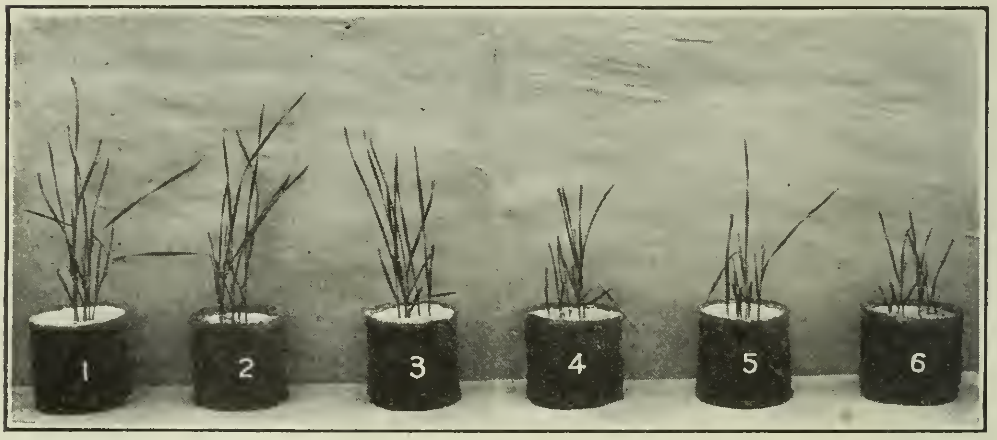
The vanillin was quite harmful in amounts of 400 and 500 parts per million in the Florida sand, and was only moderately harmful in amounts of 100 to 300 parts per million. With the Susquehanna sandy loam the vanillin reduced growth considerably when applied at the rate of 300, 400, and 500 parts per million. It was slightly harmful with 100 and 200 parts per million. Vanillin had no harmful effect in the Hagerstown loam: two of the treatments were slightly above the check and three slightly below. The growth in the untreated soil of the Hagerstown loam was better than in the Susquehanna sandy loam and considerably better than in the Florida sand. The effect of vanillin in the Florida sand is shown in Fig. 36; in the Susquehanna sandy loam in Fig. 37, and in the Hagerstown loam in Fig. 38.

FIG. 36.



Effect of vanillin on wheat in Florida sand: No. 1, soil untreated; No. 2, vanillin 100 ppm.; No. 3, vanillin 200 ppm.; No. 4, vanillin 300 ppm.; No. 5, vanillin 400 ppm.; No. 6, vanillin 500 ppm.

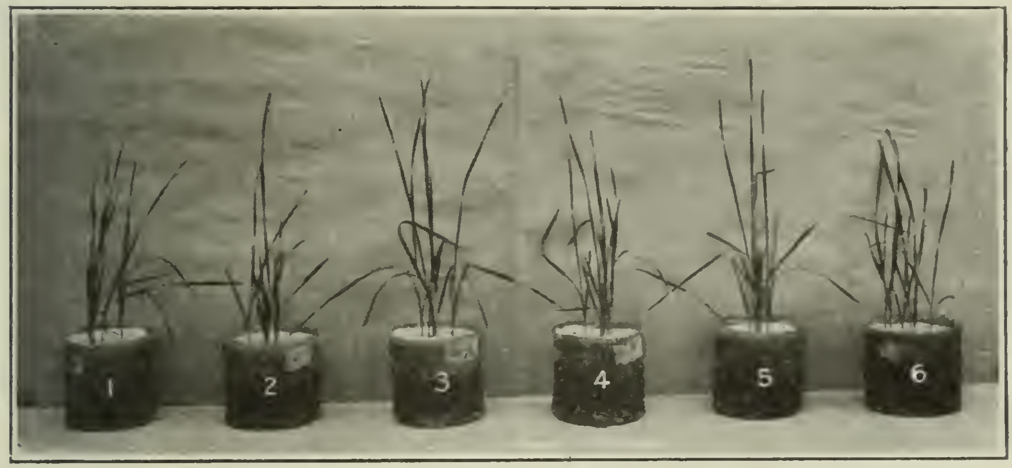
FIG. 37.



Effect of vanillin on wheat in Susquehanna sandy loam: No. 1, soil untreated; No. 2, vanillin 100 ppm.; No. 3, vanillin 200 ppm.; No. 4, vanillin 300 ppm.; No. 5, vanillin 400 ppm.; No. 6, vanillin 500 ppm.

It is seen from this experiment that vanillin is harmful in two of the soils and has no effect in the third. Vanillin is easily oxidized and changed under favorable conditions, and if this took place the action on plant growth would not be noticeable. The Florida sand was found to contain vanillin when sent in from the field, and, as would be expected, added quantities of vanillin would not be changed and it would remain as such to have its effect on plants grown in the soil. The Susquehanna sandy loam is also a soil having small oxidizing power and low life activity, and added quantities of vanillin apparently remained as such and had their effect on plant growth. The Hagerstown loam is a soil of entirely different characteristics, being highly productive, which indicated good life activities and good oxidizing power. Vanillin, when added, does not have harmful effects on plants grown in the soil, as it probably does not remain in this soil as such, but is changed or destroyed by the oxidation which is going on in soils of this character.

FIG. 38.



Effect of vanillin on wheat in Hagerstown loam: No. 1, soil untreated; No. 2, vanillin 100 ppm.; No. 3, vanillin 200 ppm.; No. 4, vanillin 300 ppm.; No. 5, vanillin 400 ppm.; No. 6, vanillin 500 ppm.

Effect of Salicylic Aldehyde and Vanillin on Different Soils and the Action of Fertilizers in Ameliorating their Harmful Properties.

Since it has been shown that vanillin and salicylic aldehyde have an effect which differs in different soils—that is, in some soils they persist and remain as such to have their effect on crops, while in others they are changed or destroyed by the life-processes of the soil, and added aldehydes have no harmful influence—other experiments were made with a number of different soils in pots to further determine the effect of these compounds on other soils of widely different characteristics.

In this work cowpeas and clover were principally grown. The soils used were gotten through soil survey parties of the U. S. Bureau of Soils in different parts of the country. In each case the soil secured was a representative one of the area from which it was taken, and in most cases it was the principal soil type encountered in that area.

This study was confined to the growth of plants in the soil to which aldehydes were added, both with and without fertilizers. The effect of the aldehyde on the soil was determined, and the effect of the commonly used fertilizers and lime and manganese in overcoming or ameliorating the action of the compounds was studied. No attempt was made to determine whether or not the aldehydes persisted in the soil as such or were changed or destroyed.

In all, nine different soils were used in this experiment; namely, the Cecil clay loam from North Carolina, the Orangeburg sandy loam from Georgia, Chester loam from Virginia, Chester loam from Maryland, Cecil sandy loam from Georgia, Volusia loam from Ohio, Holston fine sandy loam from West Virginia, Norfolk sand from Alabama, and Collington fine sandy loam from New Jersey.

The effect of both vanillin and salicylic aldehyde was quite different in these different soils. In four of them the added aldehydes produced no harmful effect on the crops grown, while in the other five the growth was reduced very markedly in some, while in others the effect was moderate. In these soils lime overcame the action of the compounds to a great extent; phosphates, nitrates, and manganese each had a marked influence.

The results of the tests on each soil are given in Table XII.

In these experiments clover, cowpeas, and wheat were grown in the soil in paraffin wire pots, and in a few cases stone crocks were used. Each pot holds approximately 12 pounds of soil. Where cowpeas were grown, four plants were grown in each pot, and in the case of clover 0.05 gramme of seed was sown in each pot. The cowpeas were grown in about six weeks, and the clover in three and a half to four months.

TABLE XII.

Effect of Aldehyde on Growth in Nine Different Soils and the Action of Fertilizers in Modifying their Effects. (Yield Expressed in Grams of Green Matter Per Pot.)

Soil	Cecil clay loam			Orange-burg sandy loam		Chester Loam (Va.)				Chester Loam (Md.)		Cecil sandy loam			Volusia loam		Hol-ston fine sandy loam	Nor-folk sand	Collington fine sandy loam	
Experiment No.	1	2	3	1	2	1	2	3	4	1	2	1	2	3	1	2	1	1	1	2
Plant	Cowpeas	Clover	Cowpeas	Cowpeas	Clover	Cowpeas	Clover	Cowpeas	Clover	Clover	Cowpeas	Clover	Clover	Cowpeas	Wheat	Clover	Cowpeas	Cowpeas	Clover	Cowpeas
Untreated soil	6.3	75.0	9.5	7.5	55.2	8.2	32.6	5.5	57.0	31.2	10.3	52.5	62.2	6.7	4.90	26.4	31.8	8.7	42.0	14.1
Untreated soil + salicylic aldehyde	2.2*	65.7	—	4.5	27.1	7.0	31.8	5.0	59.2	31.0	—	11.2	55.0	2.5	3.50	—	33.5	5.7	39.5	—
Untreated soil + salicylic aldehyde + acid phosphate	5.5	67.0	—	6.2	56.3	7.8	36.8	—	—	33.7	—	28.0	—	—	—	—	35.4	9.8	41.0	—
Untreated soil + salicylic aldehyde + sodium nitrate	4.8	63.5	—	5.2	33.2	6.5	35.6	—	—	22.3	—	25.0	—	—	—	—	34.7	7.0	47.5	—
Untreated soil + salicylic aldehyde + manganese sulphate	—	—	—	—	—	—	—	4.9	63.1	—	—	—	73.1	4.0	4.15	—	—	—	—	—
Untreated soil + salicylic aldehyde + ferrous sulphate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5.00	—	—	—	—	—
Untreated soil + lime + salicylic aldehyde	3.1	87.0	—	7.9	62.3	8.0	32.5	—	—	36.8	—	70.0	—	—	—	—	—	—	80.2	—
Untreated soil + lime + salicylic aldehyde + acid phosphate	5.3	123.5	—	7.9	63.8	7.9	32.8	—	—	40.3	—	82.5	—	—	—	—	—	—	84.5	—
Untreated soil + lime + salicylic aldehyde + sodium nitrate	4.9	102.0	—	9.0	63.4	7.6	35.2	—	—	31.5	—	47.5	—	—	—	—	—	—	90.0	—
Untreated soil + vanillin	—	—	6.6	—	—	—	—	—	—	—	9.5	—	—	—	4.25	21.2	30.2	5.9	—	16.4
Untreated soil + vanillin + acid phosphate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	34.7	—	—	—
Untreated soil + vanillin + sodium nitrate	—	—	8.3	—	—	—	—	—	—	—	9.7	—	—	—	—	—	33.2	—	—	16.3
Untreated soil + vanillin + manganese sulphate	—	—	9.5	—	—	—	—	—	—	—	9.2	—	—	—	4.55	42.2	—	—	—	15.5
Untreated soil + vanillin + ferrous sulphate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.15	—	—	—	—	—
Untreated soil + lime + vanillin	—	—	10.0	—	—	—	—	—	—	—	10.2	—	—	—	—	—	—	—	—	17.1
Untreated soil + lime + vanillin + sodium nitrate	—	—	—	—	—	—	—	—	—	—	9.8	—	—	—	—	45.9	—	—	—	—
Untreated soil + lime + vanillin + manganese sulphate	—	—	11.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Untreated soil + acid phosphate	5.8	90.5	—	8.3	68.7	8.5	42.7	—	—	39.4	—	58.3	—	—	—	—	36.4	15.5	46.9	16.2
Untreated soil + sodium nitrate	5.0	80.0	—	8.0	64.4	7.0	34.3	—	—	30.2	11.5	60.2	—	—	—	—	33.0	11.7	50.9	17.8
Untreated soil + manganese sulphate	—	—	—	—	—	—	—	6.0	60.2	—	11.4	—	69.5	7.6	5.10	31.7	—	—	—	15.0
Untreated soil + ferrous sulphate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5.45	—	—	—	—	—
Untreated soil + lime sulphate	7.5	90.9	—	9.0	62.1	8.6	33.6	—	—	38.0	—	72.9	—	—	—	37.9	—	—	83.3	—
Untreated sulphate + lime + acid phosphate	4.5	114.2	—	10.2	61.6	7.8	44.0	—	—	37.7	—	80.0	—	—	—	—	—	—	85.9	—
Untreated soil + lime + sodium nitrate	4.0	107.7	—	9.5	64.0	7.9	38.0	—	—	39.7	—	75.5	—	—	—	—	—	—	91.2	—
Untreated soil + lime + manganese sulphate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	38.2	—	—	—	—

* 2 plants died, figures represent weight of 2 plants only.

The fertilizing materials used in these experiments were all applied before the soil was potted and planted. They were well mixed in the soil. The salicylic aldehyde and vanillin were applied in three applications. One-third of the total amount was added to the soil before planting, one-third two to three weeks after planting, and the remaining one-third was added two to three weeks after the second application. In these experiments salicylic aldehyde was used at the rate of 200 pounds per acre, vanillin 400 pounds per acre, acid phosphate 360 pounds, sodium nitrate 180 pounds, lime ($CaCO_3$) two tons per acre, manganese sulphate 100 pounds, and ferrous sulphate 50 pounds per acre. This work was conducted in the greenhouse in the fall of 1914 and the winter and spring of 1915.

Cecil Clay Loam.—The soil used in this experiment was taken from Lincoln County, North Carolina, in the Piedmont Plateau region (2). The surface soil is brown to red clay loam, ranging in depth from 5 to 8 inches. The subsoil is a red stiff clay, brittle when dry, but sticky and plastic when wet. The soil is residual in origin, having been derived from the weathering of the rock formations, composed mainly of quartz and feldspar, with some mica and hornblends. It is fertilized usually with acid phosphate and produces about 300 pounds of lint cotton per acre. When the soil was collected the field was growing cowpeas. For three years previous to this it grew cotton. The field was reported as being well drained.

A laboratory examination showed the soil to be acid; its oxidative power was poor—a little less than the run of average field soils.

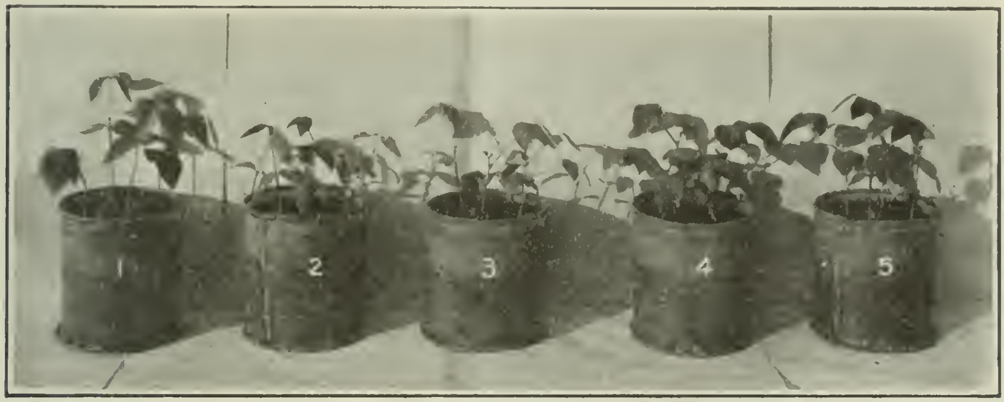
The effect of salicylic aldehyde in the Cecil clay loam was tested by growing cowpeas and clover, and the results are given in Table XII, experiments Nos. 1 and 2.

The aldehyde reduced the growth of both cowpeas and clover in this soil. Two of the cowpea plants in the pots treated with the aldehyde, unfertilized and limed, were killed; the weights given are the weights of the two plants that were living at the end of the experiment. The untreated soil produced 6.3 grammes green weight, and the salicylic aldehyde pot produced 2.2 grammes for two plants, or 4.4 grammes calculated for four plants. With acid phosphate the aldehyde was less harmful, and the sodium nitrate only slightly less. In the limed soil the effect was also marked.

The growth of clover was also reduced by the aldehyde used alone and with fertilizers, but it had practically no effect in the limed soil. Lime and acid phosphate overcame its effect entirely, and lime and sodium nitrate to a great extent.

The effect of vanillin with and without certain fertilizers was also tested in this soil. In this experiment cowpea plants were grown; the results are given in experiment No. 3. Vanillin proved harmful, reducing the growth of the cowpeas from 9.5 grammes to 6.6 grammes. Sodium nitrate partly overcame its effect, and lime and manganese sulphate overcame the harmful influence entirely. The effect of vanillin and the ameliorating effect of the fertilizers are shown in Fig. 39.

FIG. 39.



Effect of vanillin on cowpeas in Cecil clay loam and the action of lime and manganese in altering its effects: No. 1, soil untreated; No. 2, vanillin; No. 3, same + sodium nitrate; No. 4, same + lime; No. 5, same + manganese.

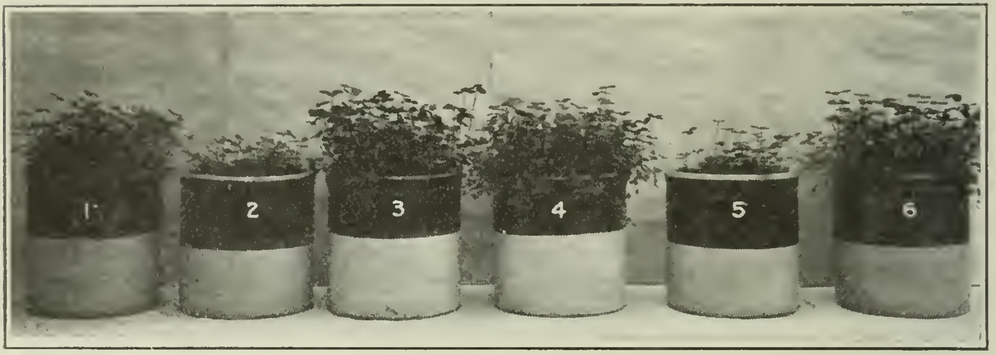
Orangeburg Sandy Loan.—The Orangeburg sandy loam (73) used in the aldehyde test was taken from Clay County, near Fort Gaines, Ga. It is a coastal plains soil and is a grayish loamy sand, underlain at 5 or 6 inches by light-reddish loamy sand. The subsoil is a red, friable sandy clay which extends to a depth of 3 feet or more. It is not a productive soil, and requires heavy applications of fertilizers to maintain a satisfactory crop. General farm crops are grown on the type. The field from which the sample was taken was growing cotton, and has grown cotton for the past 12 years. The soil was found to be acid, and its oxidizing power was very low.

Cowpeas and clover were used to test the effect of salicylic aldehyde, with and without fertilizers, in the Orangeburg sandy loam. The green weight yields are given in Table XII, experiments Nos. 1 and 2.

By an examination of the table it is seen that salicylic aldehyde reduced the growth of both cowpeas and clover. The green weight of the cowpeas was reduced from 7.5 grammes to 4.5 grammes. With acid phosphate the aldehyde reduced growth to only 6.2 grammes. Sodium nitrate also lessened the effect of the aldehyde slightly, but not so much as the phosphate fertilizer. The aldehyde was only slightly harmful in the limed soil.

The aldehyde reduced the green weight of the clover from 55.2 grammes to 27.1 grammes. Its harmful effect was partly overcome by phosphate fertilizers and entirely overcome by lime. Sodium nitrate had only a small influence in lessening its harmfulness in this soil. The growth of the clover as affected by salicylic aldehyde in this soil and the action of fertilizers in overcoming its effect are shown in Figs. 40 and 41. In Fig. 40 the effect of the aldehyde on clover is shown in pot No. 2, and it is here seen that the growth is much smaller than its check pot No. 1. Pot No. 3, which contains phosphate with aldehyde, has produced as good growth as the check. It is also seen in pot No. 5, which had aldehyde with nitrate, that the growth is about the same as in the pot which has aldehyde alone. In the limed set shown in Fig. 41 the growth in all the pots appears about the same.

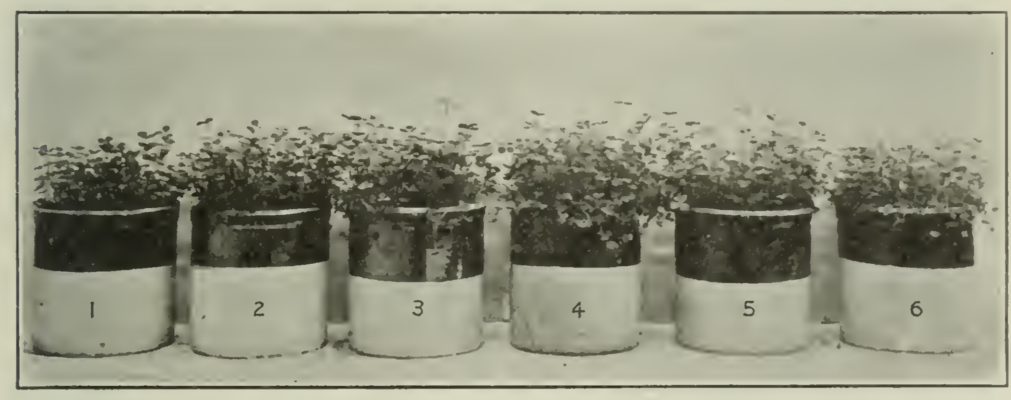
FIG. 40.



Effect of salicylic aldehyde on clover on unlimed Orangeburg sandy loam, and the action of fertilizers in destroying its effects: No. 1, soil untreated; No. 2, salicylic aldehyde; No. 3, same plus acid phosphate; No. 4, acid phosphate; No. 5 salicylic aldehyde plus sodium nitrate; No. 6, sodium nitrate.

Chester Loam (*Virginia*).—The next experiment was made on the Chester loam from McLain, Fairfax County, Virginia (14). The field from which the soil was taken produces excellent crops of corn, grass, and wheat. It is naturally a productive soil, and has been manured well for several years with stable and barnyard manure. The Chester soil occupies an extensive area in Fairfax County. The surface soil is a brown to yellowish-brown, friable loam, 8 to 12 inches deep; the subsoil is yellowish-brown clay loam. The soil lies in the Piedmont Plateau and has weathered deep its parent rock. It is well drained, and the soil responds to general fertilizer treatments. The soil is neutral in reaction; it has a very strong oxidizing power.

FIG. 41.



Effect of salicylic aldehyde on clover in limed Orangeburg sandy loam: No. 1, soil untreated; No. 2, salicylic aldehyde; No. 3, salicylic aldehyde + acid phosphate; No. 4, acid phosphate; No. 5, salicylic aldehyde + sodium nitrate; No. 6, sodium nitrate.

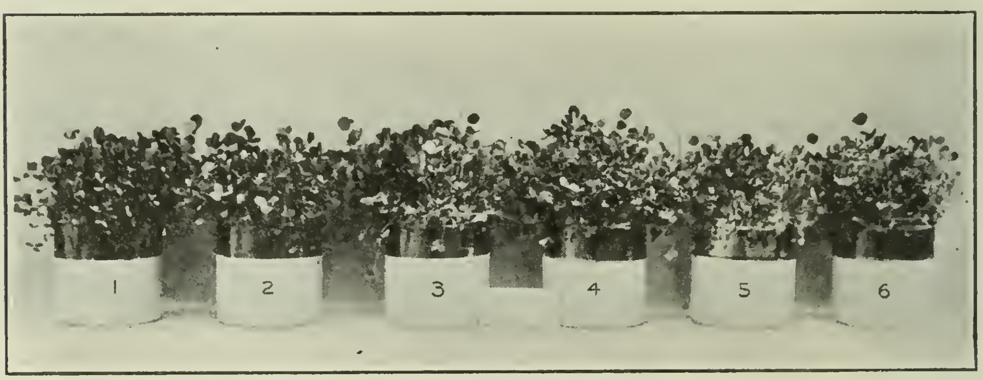
Clover and cowpeas were grown to study the effect of salicylic aldehyde in the Chester loam; the results are given in Table XII, experiments Nos. 1, 2, 3, and 4. As seen by the green weight figures, the aldehyde had only a very slight effect in reducing growth. This is true with both cowpeas and clover. The slight differences that exist show a slight harmfulness of the aldehyde, and these differences are so very slight that it is easily within the range of experimental error, and it seems fair to conclude that salicylic aldehyde has no harmful effect in this productive strong soil.

Chester Loam (Maryland).—This sample of Chester loam was taken from Montgomery County, Maryland (13), and, like the Chester loam from Virginia, it is a productive fertile soil, having strong oxidizing power, and is otherwise a strong soil on which good cultural methods have been practised. The soil has been fertilized with commercial fertilizer from year to year, and in 1913 was limed heavily. The soil produces good yields of corn, wheat, and hay. It is neutral in reaction.

The soil lies in the Piedmont Plateau and is derived from the underlying rock. It is the most extensive type in Montgomery County; is easily tilled and does not clod or break badly on drying.

As seen in Table XII, experiment No. 1, salicylic aldehyde had no injurious effect on this soil. Clover was grown and a good crop produced. An examination of the table will show that the only depression from the salicylic aldehyde treatment was when used with sodium nitrate. This is true in both the unlimed and limed pots. From this it would seem that the effect of salicylic aldehyde was worse with sodium nitrate fertilizers. This, however, has not been the case with the other experiments made, and may be merely an accident here. The uniform growth from each of the treatments is shown in Fig. 42.

FIG. 42.



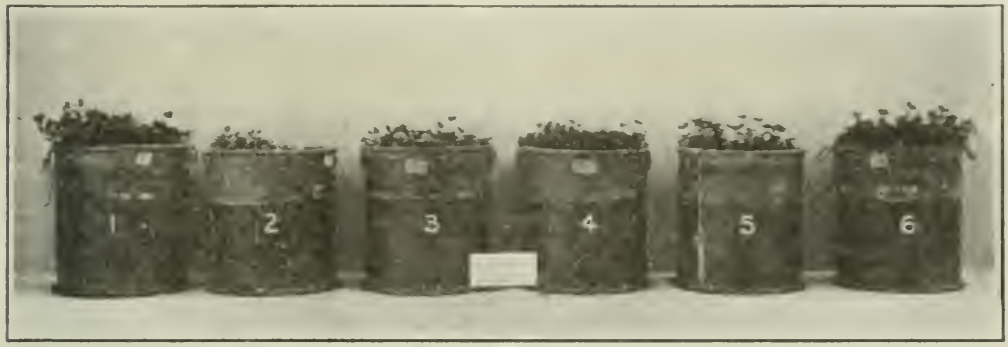
Effect of salicylic aldehyde on clover in unlimed Chester loam: No. 1, soil untreated; No. 2, salicylic aldehyde; No. 3, same + acid phosphate; No. 4 acid phosphate; No. 5, salicylic aldehyde + sodium nitrate; No. 6, sodium nitrate.

An experiment testing the effect of vanillin on this soil was also made, and the results are given in Table XII, experiment No. 2. Cowpeas were grown. Vanillin, like the salicylic aldehyde, had no harmful action; the green weight figures show that all of the treatments made about equal growth.

Cecil Sandy Loam.—The Cecil sandy loam on which the pot tests were made was taken from near Decatur, Dekalb County, Georgia (29). It is a gray to grayish-brown sandy loam; the subsoil is a red, friable sandy loam which grades into a heavy, stiff red clay. It is a widely distributed type of the Piedmont Plateau. The field from which the soil was taken grew cotton for the past three years, producing about one-half bale per acre.

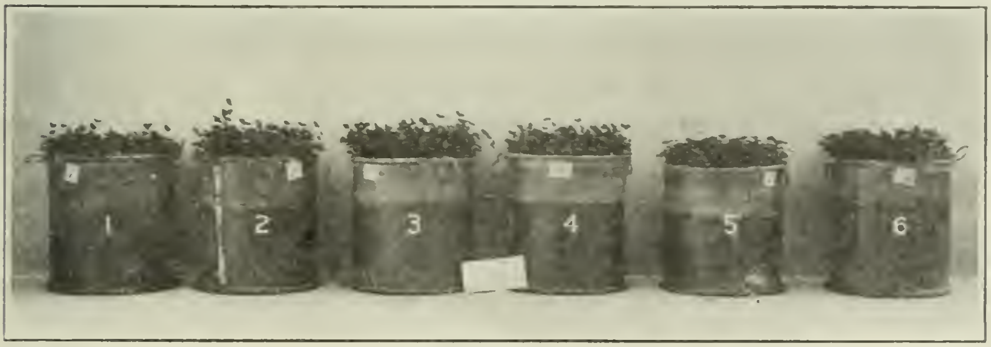
When examined in the laboratory the soil was found to be acid. Its oxidizing power was very low, about one-half as strong as the Chester loam, and it was without reducing power.

FIG. 43.



Effect of salicylic aldehyde on clover in unlimed Cecil sandy loam: No. 1, soil untreated; No. 2, salicylic aldehyde; No. 3, same + acid phosphate; No. 4, acid phosphate; No. 5, salicylic aldehyde + sodium nitrate; No. 6, sodium nitrate.

FIG. 44.



Effect of salicylic aldehyde on clover in limed Cecil sandy loam: No. 1, soil untreated; No. 2, salicylic aldehyde; No. 3, same + acid phosphate; No. 4, acid phosphate; No. 5, salicylic aldehyde + sodium nitrate; No. 6, sodium nitrate.

The first test with salicylic aldehyde and fertilizers was made by growing clover in paraffin wire pots holding ten pounds of soil.

The aldehyde proved to be very harmful in this soil, as shown in Table XII, experiment No. 1. The yield of clover was reduced in weight from 52.5 grammes for the check to 11.2 grammes. With acid phosphate fertilizers it was not quite so harmful. The acid phosphate pot yielded 58.3 grammes, and aldehyde plus phosphate 28.0 grammes. The phosphate had a slight effect in ameliorating the harmfulness of the compound. With sodium nitrate the difference in yield was greater. The nitrate pot gave 60.2 grammes green weight, while the pot with nitrate plus aldehyde gave only 25.0 grammes green weight. The aldehyde had no harmful effect on the limed soil. In Fig. 43 is shown the clover with different treatments in the unlimed soil, and in Fig. 44 is shown the clover in the limed soil. It is here seen that the aldehyde is harmful on the unlimed soil and is not harmful in the limed soil.

The action of manganese and its effect in ameliorating the harmfulness of salicylic aldehyde were also studied in this soil. An experiment was made growing cowpeas and one growing clover.

Considering the cowpeas first, it is seen that the aldehyde reduced the growth approximately 50 per cent., and that the manganese lessened its harmfulness.

With the clover the aldehyde reduced the growth greatly, but not so much as it did the cowpeas. In this test the manganese entirely overcame its harmful effect. The clover is shown growing in pots with different treatments in Fig. 45.

In this soil, at least, manganese is about as effective as phosphates in destroying the effects of salicylic aldehyde.

Volusia Loam.—Interesting results were secured on the action of manganese on the effect of vanillin and salicylic aldehyde in Volusia loam.

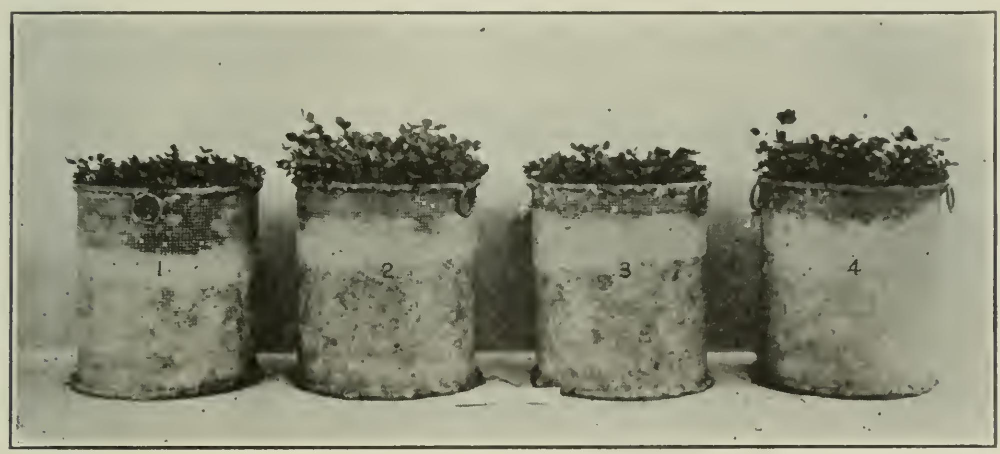
The soil was taken from Portage County, Ohio (33). The Volusia loam is of glacial origin and is largely derived from unmodified till. The surface soil has an average depth of 6 to 8 inches. It varies in color from light brown to brownish-gray. The subsoil is a pale yellow loam or silty loam and somewhat heavier than the surface soil. Gravel and small stone, and to some extent boulders, are found scattered over the surface and through the soil mass. It is a good general farming soil, growing corn and small grain well.

The soil used in these tests was found to be acid; it has a good oxidizing power.

The first experiment made with this soil was in small paraffin wire pots holding 400 grammes of soil. Five pots were used for each treatment. Six wheat plants were grown in each pot for about one month. The materials used were all added and mixed thoroughly with the soil before potting and planting. Vanillin was used in amounts of 400 pounds per acre, and salicylic aldehyde 200 pounds per acre. Wheat was planted January 28 and grew until February 25, 1915. The green weights are given in Table XII, experiment No. 1. The weights for each treatment represent the growth in five pots, thirty plants in all.

The wheat plants were grown in these small pots for only 28 days, yet some indications of the action of vanillin and salicylic aldehyde and the effect of manganese and iron on their action in this soil are shown. Vanillin reduced growth slightly; manganese had some effect on its action, for the vanillin produced slightly heavier plants where manganese was applied to the soil. The iron sulphate seems to have had no beneficial action on the harmfulness of vanillin.

FIG. 45.



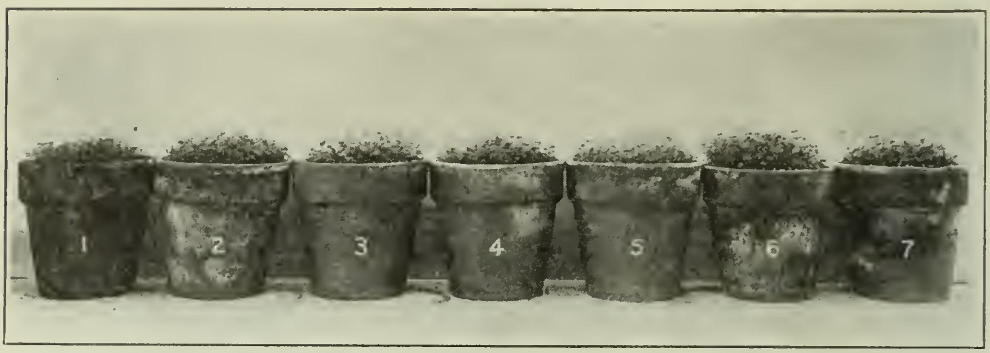
Effect of salicylic aldehyde on clover in Cecil sandy loam: No. 1, soil untreated; No. 2, manganese sulphate; No. 3, salicylic aldehyde; No. 4, salicylic aldehyde + manganese sulphate.

Salicylic aldehyde was also slightly harmful, even more so than the vanillin, and both manganese and iron ameliorated its harmfulness.

Another experiment was made to further test the influence of the catalytic fertilizers on the action of vanillin. This time clover was grown in 8-inch earthenware pots, which hold 8 pounds of soil. The vanillin was added at the rate of 500 pounds, periodically as described at the beginning of this chapter.

As seen in the table, experiment No. 2, this soil responded well to manganese and to lime. Vanillin in the amount used, 500 pounds per acre, produced a decreased yield, but this decreased growth is much smaller than in some soils as recorded in this paper. Both manganese and lime entirely overcame the effect of the vanillin. The growths in the pots receiving vanillin, which were fertilized with manganese and with manganese plus lime, were the best in the series. The growth of the clover as affected by the different treatments is shown in Fig. 46.

FIG. 46.



Effect of vanillin on clover in Volusia loam, and the action of manganese and lime in overcoming its effect: No. 1, soil untreated; No. 2, $MnSO_4$; No. 3, lime; No. 4, lime + $MnSO_4$; No. 5, vanillin; No. 6, same + $MnSO_4$; No. 7, same + $MnSO_4$ + lime.

Holston Fine Sandy Loam.—The Holston fine sandy loam used in the aldehyde experiment is naturally a strong productive soil. The field from which the soil was taken was manured yearly with stable manure in amounts of 20 to 25 loads per acre, and 250 pounds per acre of a high-grade fertilizer was applied. The field was in corn when the sample was taken; previously it had grown vegetables for years. The soil was neutral and had a strong oxidizing power.

The Holston loam (27) is a brownish, light, fine sandy loam and is underlaid at about 10 inches by yellow, compact, fine sandy loam. Drainage is good. The soil occurs on old alluvial terraces and consists principally of material washed from gray shales and sandstones. It is easy to cultivate, requiring only light implements, and responds readily to manure and fertilizers.

The experiment was conducted in paraffin wire pots holding 10 pounds of soils, and four cowpeas were grown in each pot. Vanillin was used at the rate of 400 pounds per acre, salicylic aldehyde, acid phosphate, and sodium nitrate at the rate of 200, 360, and 180 pounds, respectively, per acre. The cowpeas were planted October 22, 1915, and made an excellent growth, producing large stalks and luxuriant foliage. The green weights of the peas were taken December 8.

As seen in Table XII, neither salicylic aldehyde nor vanillin had any harmful effect. The untreated soil produced 31.8 grammes green weight, salicylic aldehyde 33.5 grammes, and vanillin 30.2 grammes. The growth in the fertilized pots containing the aldehydes was also greater than the untreated soil and about the same as the pots which contained the fertilizers without any aldehyde. It is apparent, then, that the aldehydes do not have any bad effects in this soil.

Norfolk Sand.—One of the samples of Norfolk sand used in these tests was taken from near Clayton, Barbour County, Alabama (72). This soil type occupies nearly level to rolling uplands throughout the Coastal Plain, and has been derived from unconsolidated sedimentary material. This soil is well drained, sometimes excessively. Its porous texture allows it to absorb nearly all the rainfall, and in wet seasons it becomes waterlogged. The surface soil is a loose, incoherent, grayish sand from 4 to 6 inches deep. The subsoil is a pale-yellow sand which extends to a depth of 3 feet. Iron concretions are common, and fine gravel occurs. The soil produces about one-fourth bale of cotton and about 10 bushels of corn per acre.

Cowpeas were grown in the test with this soil, and the effects of both salicylic aldehyde and vanillin were determined. The results are given in Table XII, in the Norfolk sand column.

Salicylic aldehyde reduced growth from 8.7 grammes for the check to 5.7 grammes. The peas responded well to both acid phosphate and sodium nitrate, especially the phosphate. The acid phosphate also increased the growth considerably in the pot to which the aldehyde was added, partly overcoming its harmful effect. Vanillin was also harmful in this soil. The green weight of the vanillin-treated pot was 5.9 grammes, against 8.7 grammes for the untreated pot.

Collington Fine Sandy Soil.—This soil was taken from a field near Marlton, N. J. It lies within the Atlantic Coastal Plain and is derived from the beds of unconsolidated sand, sandy clay, gravel, and marl. These beds are composed of material which was transported from older land areas and deposited under marine conditions. The Collington fine sandy loam consists of a brown, fine sandy loam underlaid at about 8 to 12 inches by yellowish, fine sandy loam (34). The lower subsoil is more friable than the upper subsoil. This type is the most important soil of the Camden area. It is chiefly devoted to the growing of potatoes, tomatoes, and vegetable crops, and yields well.

The soils, as a rule, are highly manured. The field from which the sample was taken has grown potatoes for five years, and was highly manured with stable manure and commercial fertilizers. Lime was added in 1914. The sample, however, when taken from the field and examined in the laboratory, was found to be acid.

Two experiments in pots were made with the Collington fine sandy loam. In the first, testing the effect of salicylic aldehyde, clover was grown, the results of which are given in Table XII.

As is seen in the green weight column in the table, the salicylic aldehyde had practically no effect in this soil. The clover responded well to the fertilizers and lime. In any case, there was only a very slight reduction in growth due to the aldehyde, and there was no effect whatever in the limed soil.

In the second experiment the effect of vanillin and the action of nitrate, manganese, and lime in ameliorating its effect were studied. In this case cowpeas were grown. No harmful effect was observed from the added vanillin; in fact, there was a slight increased growth in the vanillin-treated pot. Sodium nitrate, manganese, and lime each produced an increase over the check. From the results of the two experiments it will have to be concluded that aldehydes are not harmful in this soil.

(*To be continued.*)

PHYSICS OF THE AIR.*

BY

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CHAPTER XV (*Continued*).

AURORA POLARIS

The aurora polaris is a well-known but imperfectly understood luminous phenomenon of the upper atmosphere, of which Figs. 120 and 121, from Störmer's numerous photographs, are good examples.

Types.—While no two auroras are exactly alike, several types have been recognized, such as arcs, bands, rays, curtains or draperies, coronas, luminous patches, and diffuse glows. The arcs normal to the magnetic meridian, often, but not always, reach the horizon. Their under edge is rather sharply defined, so that by contrast the adjacent portion of the sky appears exceptionally dark. The rays, sometimes extending upward from an arch, at other times isolated, are parallel to the lines of magnetic force. Many auroras are quiescent, others exceedingly changeable, flitting from side to side like wandering searchlights, and in some cases even waving like giant tongues of flame.

Latitude Variation.—The aurora of the northern hemisphere occurs most frequently, about 100 per year, at the latitudes 60° (over the North Atlantic and North America) to 70° (off the coast of Siberia). Its frequency appears to be less within this boundary, while with decrease of latitude it falls off so rapidly that even in southern Europe it is a rare phenomenon. At the same latitude it is distinctly more frequent in North America than in either Europe or Asia.

The distribution of auroras in the southern hemisphere is not so well known, but it appears to be similar, in general, to that of the northern.

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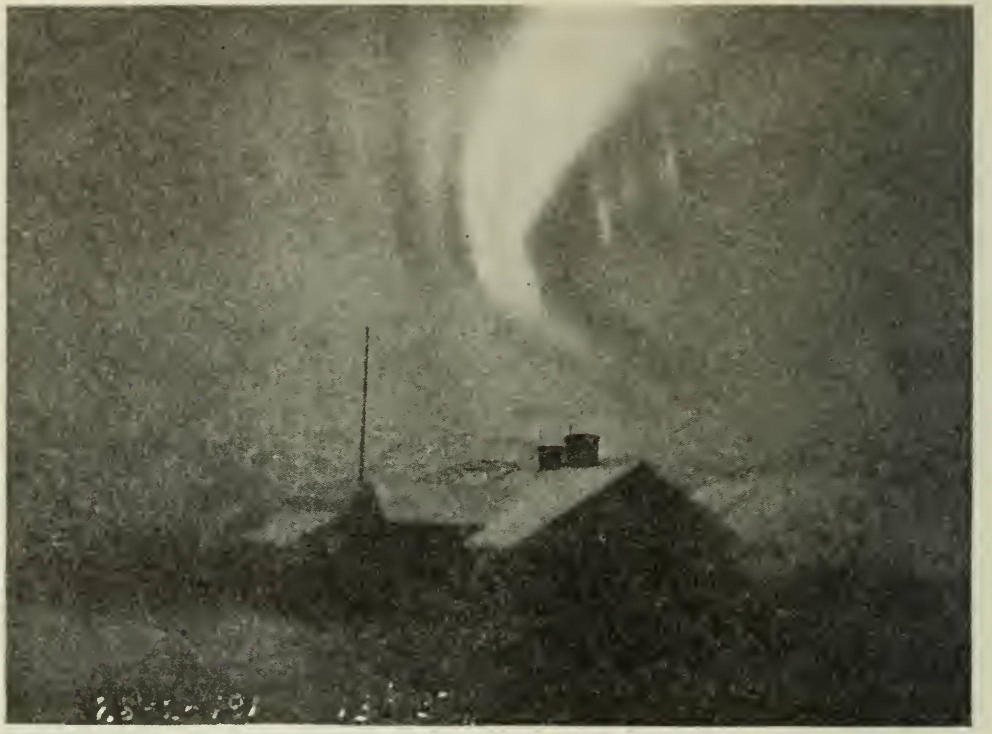
* Concluded from page 370, Vol. 186, September, 1918.

Periodicity.—It is well established that on the average auroras are more numerous during years of sun spot maxima than during years of spot minima. They also appear to be more numerous before midnight than after. Relations of frequency to phase of the moon, season, et cetera, have also been discussed, but with no conclusive results.

Fig. 120.



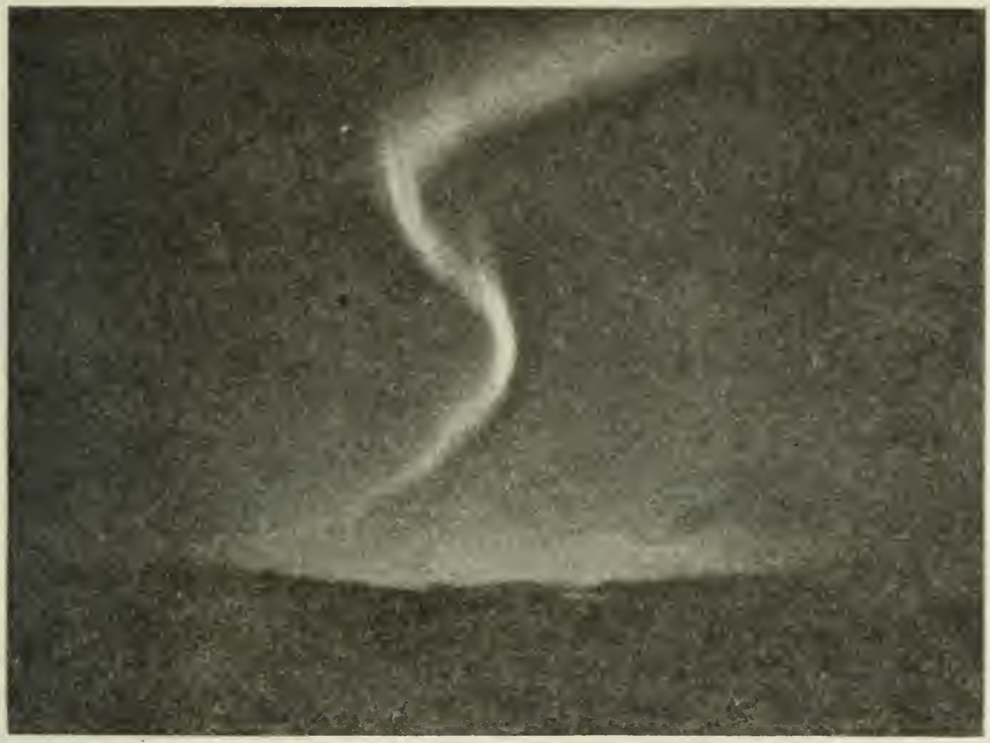
Aurora, February 28, 1910. (Störmer.)

Color.—Many auroras are practically white. Red, yellow and green are also common auroral colors. Some streaks and bands are reddish through their lower (northern) portion, then yellowish, and finally greenish through the higher portions. Much of the light is due to nitrogen bands, but the source of the most prominent line of the auroral spectrum, $\lambda\ .557\ \mu$ (green), is not known. It has often been attributed to krypton, but other conspicuous krypton lines are absent; besides krypton is too heavy to exist at auroral heights in sufficient abundance to produce a spectrum of such brilliance.

There is good evidence that this green light, the light that produces the "auroral line," is always present in the sky, though whether wholly of auroral origin, or due in part to bombardment by meteoric dust, or to some other cause, is not known.

Height.—The problem of the height of auroras has often been investigated, but only recently solved. By simultaneously photographing the same aurora from two stations against a common background of stars, Fig. 122, and measuring the parallax obtained, Störmer,[163] and Vegard and Krogness[164] have secured many excellent height measurements. The upper limits of the auroral light vary from about 100 kilometers to over 300 kilo-

FIG. 121.



Aurora, March 3, 1910. (Störmer.)

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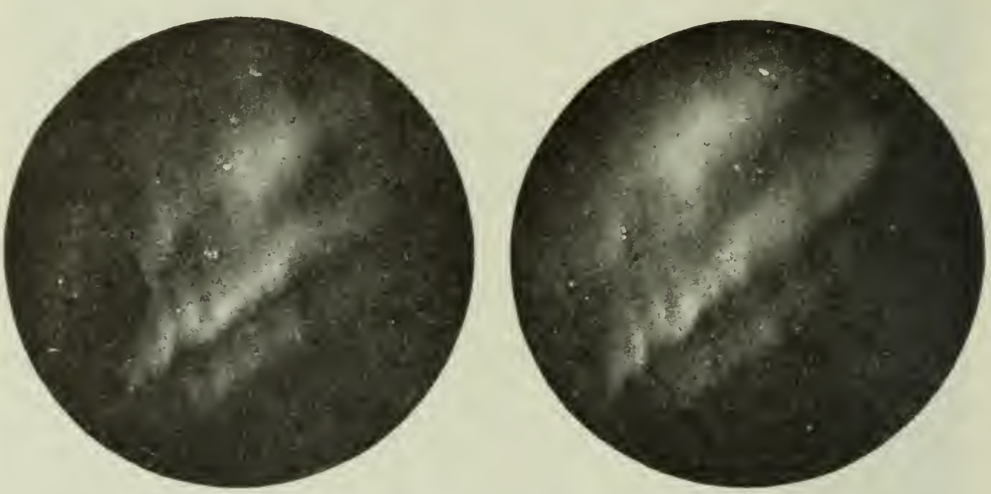
[163] *Terr. Magnet. and Atmos. Elec.*, 21, p. 157, 1916.

[164] *Terr. Magnet. and Atmos. Elec.*, 21, p. 169, 1916.

meters; and the lower limits from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, one at 100 kilometers, the other at 106 kilometers.

Cause.—The fact that brilliant shifting auroras are accompanied by magnetic storms renders it practically certain that they, and presumably therefore all auroras, are due to electric discharges; and the further fact that they vary in frequency with the sunspot period indicates that this current either comes from or is induced by the sun. For some time it was thought probable that auroras are caused by negative particles shot off from the sun, and entrapped by the magnetic field of the earth. On the other hand, Vegard [165] has given strong arguments in favor of the α particle which is positively charged, and Störmer[166] has found at least one case that required the positive charge to account for the observed magnetic disturbance.

FIG. 122.



Parallactic auroral-photographs for determining altitude. (Störmer.)

The evidence, then, while not conclusive, indicates that auroras are due to streams of α particles in the upper atmosphere shot off by radioactive substances in the sun.

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[165] *Phil. Mag.*, 23, p. 211, 1912.

[166] *Terr. Magnet. and Atmos. Elec.*, 20, p. 1, 1915.

APPENDIX.

GRADIENT WIND VELOCITY TABLES.

To be used only in the absence of local disturbances—thunderstorms, line squalls, and the like—and when the isobars, as drawn, are free from any considerable reduction or other errors. Also to be used with discretion in the case of east winds in the middle latitudes, since at an altitude of 1 kilometer or more their actual velocities are likely to be less than the computed, as explained on page 670, Nov., 1917.

To find from the following tables the probable wind velocity at 1 to 2 kilometers elevation over any given place, one notes, *a,* the current system of winds, cyclonic or anticyclonic, at that place (this determines which table to use); *b,* the latitude of the place in question (this determines the latitude division of the table in which the desired value is to be found); *c,* the pressure gradient shown on the concurrent weather map in terms of the difference of the barometer reading in millimeters per 100 kilometers at right angles to the nearest isobar (this, through the closest tabulated gradient, locates the gradient division of the value sought); and, finally, *d,* the radius of curvature, in kilometers, of this isobar (a sufficiently close practical value of r) at the place in question, on line with which the desired velocity is given in meters per second, kilometers per hour, and miles per hour. The wind at the given levels is roughly parallel to the corresponding surface isobar, and so directed that on following it one will have the lower pressure to his left.

In using these tables in conjunction with weather maps whose barometric interval is 0.1 inch, the interval used in the United States, it is only necessary in taking step *c* to note the number of miles between the 0.1 inch isobars and then select from the second expressions in the first columns the nearest to an equal gradient.

The actual gradient, radius of curvature, density, and latitude usually will all differ somewhat from the tabulated values, but as the latter, except the density, which may be computed approximately, are given for small intervals it would be easy to add, with their proper signs, interpolated corrections. In practice, however, this will hardly be necessary, partly because of the great number of intervals directly supplied by the tables themselves, and partly because actual velocities and computed gradient velocities are likely to differ too much to justify minute corrections. They differ because the atmosphere never attains to a fixed or steady state of motion; because the actual density is likely to differ from that assumed; and because the gradient at the level for which computation is made is not, as a rule, exactly the same as that given on the maps.

In regions of great elevation, 1 kilometer or more, the isobaric lines, if drawn, as they commonly are, in accordance with values obtained by reduction of the barometer to sea level, may be seriously in error during both unusually warm and exceptionally cold weather. Obviously, therefore, it is not safe, at such times and places, to use the reduced distribution of isobars for the calculation of gradient winds—nor, indeed, for any other purpose.

The first line in each section of the anticyclonic table gives the maximum velocity for the given density and pressure gradient and the corresponding radius of curvature of the path. It will be noticed that this limiting radius grows smaller as the gradient is decreased, in accordance with the fact that steep gradients and strong winds can not occur near the center of an anticyclonic region.

TABLE I.

Gradient Wind Velocity for Cyclonic Movement.

(Computed for $\rho = .0011$, a density that obtains at an elevation of about 1 kilometer above sea level.)

$\frac{\triangle B\ (mm.)}{100\ km.}$ = barometric gradient, or difference of barometric reading in millimeters per 100 kilometers at right angles to isobars $= \frac{\triangle B\ (\text{tenths } in.)}{158\ mi.}$

r = radius of curvature of isobars in kilometers.

$V\frac{m}{s}$ = velocity in meters per second.

$V\frac{km}{hr}$ = velocity in kilometers per hour.

$V\frac{mi}{hr}$ = velocity in miles per hour.

Latitude 25°.

$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	2.73	9.83	6.11	$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	5.99	21.56	13.40
	200	3.13	11.27	7.00		200	7.38	26.57	16.51
	300	3.33	11.99	7.45		300	8.18	29.45	18.30
	400	3.45	12.42	7.72		400	8.71	31.36	19.49
	500	3.53	12.71	7.90		500	9.10	32.76	20.36
	600	3.58	12.89	8.01		600	9.40	33.84	21.03
	700	3.63	13.07	8.12		700	9.64	34.70	21.56
	800	3.66	13.18	8.19		800	9.83	35.39	21.99
	900	3.69	13.28	8.25		900	9.99	35.96	22.34
	1000	3.71	13.36	8.30		1000	10.13	36.47	22.66
	1200	3.74	13.46	8.36		1200	10.35	37.26	23.15
	1500	3.78	13.61	8.46		1500	10.58	38.09	23.67
	2000	3.81	13.72	8.53		2000	10.84	39.02	24.25
	3000	3.85	13.86	8.61		3000	11.12	40.03	24.87
	∞	3.93	14.15	8.79		∞	11.79	42.44	26.37
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	4.53	16.31	10.13	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	7.24	26.06	16.19
	200	5.45	19.62	12.19		200	9.06	32.62	20.27
	300	5.95	21.42	13.31		300	10.15	36.54	22.70
	400	6.27	22.57	14.02		400	10.90	39.24	24.38
	500	6.49	23.36	14.52		500	11.46	41.26	25.64
	600	6.66	23.98	14.90		600	11.90	42.84	26.62
	700	6.79	24.44	15.19		700	12.25	44.10	27.40
	800	6.90	24.84	15.43		800	12.54	45.14	28.05
	900	6.98	25.13	15.62		900	12.78	46.01	28.59
	1000	7.05	25.38	15.77		1000	12.99	46.76	29.05
	1200	7.17	25.81	16.04		1200	13.32	47.95	29.79
	1500	7.29	26.24	16.30		1500	13.69	49.28	30.62
	2000	7.42	26.71	16.60		2000	14.11	50.80	31.57
	3000	7.55	27.18	16.89		3000	14.58	52.49	32.62
	∞	7.86	28.30	17.58		∞	15.72	56.59	35.16

Latitude 25° (Continued.)

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	8.35	30.06	18.68	$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	14.59	52.52	32.63
	200	10.58	38.09	23.67		200	19.21	69.16	42.97
	300	11.94	42.98	26.71		300	22.28	80.21	49.84
	400	12.90	46.44	28.86		400	24.60	88.56	55.03
	500	13.63	49.07	30.49		500	26.44	95.18	59.14
	600	14.20	51.12	31.76		600	27.97	100.69	62.57
	700	14.67	52.81	32.81		700	29.27	105.37	65.47
	800	15.06	54.22	33.69		800	30.40	109.44	68.00
	900	15.39	55.40	34.42		900	31.38	112.97	70.20
	1000	15.67	56.41	35.05		1000	32.26	116.14	72.17
	1200	16.13	58.07	36.08		1200	33.74	121.46	75.47
	1500	16.65	59.94	37.25		1500	35.50	127.80	79.41
	2000	17.24	62.06	38.56		2000	37.64	135.50	84.20
	3000	17.92	64.51	40.08		3000	40.34	145.22	90.24
	∞	19.65	70.74	43.96		∞	49.13	176.87	109.90
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	10.75	38.70	24.05	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in}{53\ mi.}$	100	16.23	58.43	36.31
	200	13.87	49.93	31.03		200	21.49	77.36	48.07
	300	15.87	57.13	35.50		300	25.04	90.14	56.01
	400	17.32	62.35	38.74		400	27.74	99.86	62.19
	500	18.44	66.38	41.23		500	29.92	107.71	66.93
	600	19.35	69.66	43.28		600	31.73	114.23	70.98
	700	20.11	72.40	44.99		700	33.28	119.81	74.45
	800	20.75	74.70	46.42		800	34.64	124.70	77.49
	900	21.30	76.68	47.65		900	35.83	128.99	80.15
	1000	21.78	78.41	48.72		1000	36.89	132.80	82.52
	1200	22.59	81.32	50.53		1200	38.71	139.36	86.59
	1500	23.50	84.60	52.57		1500	40.88	147.17	91.45
	2000	24.58	88.49	54.99		2000	43.56	156.82	97.44
	3000	25.87	93.13	57.87		3000	47.01	169.24	105.16
	∞	29.48	106.13	65.95		∞	58.96	212.26	131.90
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	12.79	46.04	28.61	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	19.15	68.94	42.84
	200	16.70	60.12	37.36		200	25.57	92.05	57.20
	300	19.26	69.34	43.09		300	29.99	107.96	67.08
	400	21.16	76.18	47.34		400	33.39	120.20	74.69
	500	22.65	81.54	50.67		500	36.17	130.21	80.91
	600	23.88	85.97	53.42		600	38.51	138.64	86.15
	700	24.92	89.71	55.74		700	40.53	145.91	90.67
	800	25.80	92.88	57.71		800	42.31	152.32	94.65
	900	26.58	95.69	59.46		900	43.89	158.00	98.18
	1000	27.26	98.14	60.98		1000	45.31	163.12	101.36
	1200	28.40	102.24	63.53		1200	47.77	171.97	106.86
	1500	29.74	107.06	66.52		1500	50.75	182.70	113.52
	2000	31.34	112.82	70.10		2000	54.51	196.24	121.94
	3000	33.31	119.92	74.52		3000	59.48	214.13	133.05
	∞	39.31	141.52	87.94		∞	78.61	283.00	175.85

Latitude 30°.

$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	2.48	8.93	5.55	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	6.86	24.70	15.35
	200	2.79	10.04	6.24		200	8.43	30.35	18.86
	300	2.93	10.55	6.56		300	9.32	33.55	20.85
	400	3.01	10.84	6.74		400	9.92	35.71	22.19
	500	3.07	11.05	6.87		500	10.35	37.26	23.15
	600	3.10	11.16	6.93		600	10.68	38.45	23.89
	700	3.13	11.27	7.00		700	10.94	39.38	24.47
	800	3.15	11.34	7.05		800	11.16	40.18	24.97
	900	3.17	11.41	7.09		900	11.33	40.79	25.35
	1000	3.19	11.48	7.13		1000	11.48	41.33	25.68
	1200	3.21	11.56	7.18		1200	11.72	42.19	26.22
	1500	3.23	11.63	7.23		1500	11.98	43.13	26.80
	2000	3.25	11.70	7.27		2000	12.26	44.14	27.43
	3000	3.28	11.81	7.34		3000	12.57	45.25	28.11
	∞	3.32	11.95	7.43		∞	13.29	47.84	29.73
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	4.22	15.19	9.44	$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	7.95	28.62	17.78
	200	4.96	17.86	11.10		200	9.90	35.64	22.15
	300	5.34	19.22	11.94		300	11.04	39.74	24.69
	400	5.58	20.09	12.48		400	11.82	42.55	26.44
	500	5.74	20.66	12.84		500	12.40	44.64	27.74
	600	5.86	21.10	13.11		600	12.84	46.22	28.72
	700	5.95	21.42	13.31		700	13.20	47.52	29.53
	800	6.02	21.67	13.47		800	13.49	48.56	30.17
	900	6.08	21.89	13.60		900	13.74	49.46	30.73
	1000	6.13	22.07	13.71		1000	13.95	50.22	31.21
	1200	6.21	22.36	13.89		1200	14.28	51.41	31.95
	1500	6.28	22.61	14.05		1500	14.65	52.74	32.77
	2000	6.37	22.93	14.25		2000	15.06	54.22	33.69
	3000	6.56	23.62	14.68		3000	15.51	55.84	34.70
	∞	6.64	23.90	14.85		∞	16.61	59.80	37.16
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	5.63	20.27	12.60	$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	10.32	37.15	23.08
	200	6.80	24.48	15.21		200	13.12	47.23	29.35
	300	7.44	26.78	16.64		300	14.85	53.46	33.22
	400	7.85	28.26	17.56		400	16.07	57.85	35.95
	500	8.15	29.34	18.23		500	17.00	61.20	38.03
	600	8.37	30.13	18.72		600	17.73	63.83	39.66
	700	8.54	30.74	19.10		700	18.33	65.99	41.00
	800	8.68	31.25	19.42		800	18.84	67.82	42.14
	900	8.79	31.64	19.66		900	19.27	69.37	43.10
	1000	8.89	32.00	19.88		1000	19.63	70.67	43.91
	1200	9.04	32.54	20.22		1200	20.24	72.86	45.27
	1500	9.20	33.12	20.58		1500	20.92	75.31	46.80
	2000	9.37	33.73	20.96		2000	21.69	78.08	48.52
	3000	9.55	34.38	21.36		3000	22.58	81.29	50.51
	∞	9.97	35.89	22.30		∞	24.92	89.71	55.74

Latitude 30° (Continued).

$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{2.0 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{79 \text{ mi.}}$	100	12.34	44.42	27.60	$\frac{3.0 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{53 \text{ mi.}}$	100	15.77	56.77	35.27
	200	15.90	57.24	35.57		200	20.64	74.30	46.17
		18.16	65.38	40.62		300	23.85	85.86	53.35
	400	19.79	71.24	44.27		400	26.24	94.46	58.70
	500	21.06	75.82	47.11		500	28.13	101.27	62.93
	600	22.08	79.49	49.39		600	29.85	107.46	66.77
	700	22.93	82.55	51.29		700	31.00	111.60	69.34
	800	23.64	85.10	52.88		800	32.14	115.70	71.89
	900	24.26	87.34	54.27		900	33.12	119.23	74.09
	1000	24.79	89.24	55.45		1000	33.99	122.36	76.03
	1200	25.68	92.45	57.45		1200	35.46	127.66	79.32
	1500	26.71	96.16	59.75		1500	37.19	133.88	83.19
	2000	27.89	100.40	62.39		2000	39.27	141.37	87.84
	3000	29.30	105.48	65.54		3000	41.84	150.62	93.59
	∞	33.22	119.59	74.31		∞	49.84	179.42	111.49
$\frac{2.5 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{63 \text{ mi.}}$	100	14.14	50.90	31.63	$\frac{4.0 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{39 \text{ mi.}}$	100	18.67	67.21	41.76
	200	18.38	66.17	41.12		200	24.68	88.85	55.21
	300	21.13	76.97	47.27		300	28.73	103.43	64.27
	400	23.15	83.34	51.78		400	31.88	114.77	71.32
	500	24.74	89.06	55.34		500	34.26	123.34	76.64
	600	26.05	93.78	58.27		600	36.31	130.72	81.23
	700	27.12	97.63	60.66		700	38.06	137.02	85.14
	800	28.05	100.98	62.75		800	39.59	142.52	88.56
	900	28.85	103.86	64.54		900	40.93	147.35	91.56
	1000	29.55	106.38	66.10		1000	42.12	151.63	94.22
	1200	30.74	110.44	68.63		1200	44.16	158.98	98.79
	1500	32.11	115.60	71.83		1500	46.48	167.33	103.98
	2000	33.73	121.43	75.45		2000	49.59	178.52	110.93
	3000	35.70	128.52	79.86		3000	53.41	192.28	119.48
	∞	41.53	149.51	92.90		∞	66.45	239.22	148.64

Latitude 35°.

$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{789 \text{ mi.}}$	100	2.28	8.21	5.10	$\frac{0.4 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{395 \text{ mi.}}$	100	3.94	14.18	8.81
	200	2.52	9.07	5.64		200	4.55	16.38	10.18
	300	2.62	9.43	5.86		300	4.85	17.46	10.85
	400	2.68	9.65	6.00		400	5.04	18.14	11.27
	500	2.72	9.79	6.08		500	5.16	18.58	11.55
	600	2.75	9.90	6.15		600	5.24	18.86	11.72
	700	2.77	9.97	6.20		700	5.31	19.12	11.88
	800	2.78	10.01	6.22		800	5.36	19.30	11.99
	900	2.79	10.04	6.24		900	5.41	19.48	12.10
	1000	2.80	10.08	6.26		1000	5.44	19.58	12.17
	1200	2.82	10.15	6.31		1200	5.49	19.76	12.28
	1500	2.83	10.19	6.33		1500	5.55	19.98	12.42
	2000	2.85	10.26	6.38		2000	5.61	20.20	12.55
	3000	2.86	10.30	6.40		3000	5.67	20.41	12.68
	∞	2.90	10.44	6.49		∞	5.79	20.84	12.95

Latitude 35° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	5.32	19.15	11.90	$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	9.93	35.75	22.21
	200	6.31	22.72	14.12		200	12.45	44.82	27.85
	300	6.83	24.59	15.28		300	13.95	50.22	31.21
	400	7.16	25.78	16.02		400	15.00	54.00	33.55
	500	7.39	26.60	16.53		500	15.77	56.77	35.28
	600	7.55	27.18	16.89		600	16.38	58.97	36.64
	700	7.68	27.65	17.18		700	16.87	60.73	37.74
	800	7.78	28.01	17.40		800	17.28	62.21	38.66
	900	7.87	28.33	17.60		900	17.61	63.40	39.39
	1000	7.94	28.58	17.76		1000	17.90	64.44	40.04
	1200	8.04	28.94	17.98		1200	18.36	66.10	41.07
	1500	8.16	29.38	18.26		1500	18.88	67.97	42.24
	2000	8.28	29.81	18.52		2000	19.46	70.06	43.53
	3000	8.41	30.28	18.82		3000	20.11	72.40	44.99
	∞	8.69	31.28	19.48		∞	21.72	78.19	48.58
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	6.51	23.44	14.57	$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	11.93	42.95	26.69
	200	7.88	28.37	17.63		200	15.18	54.65	33.96
	300	8.62	31.03	19.28		300	17.19	61.88	38.45
	400	9.11	32.80	20.38		400	18.61	67.00	41.63
	500	9.45	34.02	21.14		500	19.69	70.88	44.04
	600	9.71	34.96	21.72		600	20.55	73.98	45.97
	700	9.91	35.68	22.17		700	21.25	76.50	47.53
	800	10.07	36.25	22.52		800	21.84	78.62	48.85
	900	10.20	36.72	22.82		900	22.34	80.42	49.97
	1000	10.31	37.12	23.07		1000	22.77	81.97	50.93
	1200	10.49	37.76	23.46		1200	23.48	84.53	52.52
	1500	10.68	38.45	23.89		1500	24.27	87.37	54.29
	2000	10.88	39.17	24.34		2000	25.18	90.65	56.33
	3000	11.10	39.96	24.83		3000	26.22	94.33	58.61
	∞	11.58	41.69	25.90		∞	28.96	104.26	64.78
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	7.59	27.32	16.98	$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	13.72	49.39	30.69
	200	9.31	33.52	20.83		200	17.63	63.47	39.44
	300	10.27	36.97	22.97		300	20.10	72.36	44.96
	400	10.92	39.31	24.43		400	21.89	78.80	48.96
	500	11.38	40.97	25.46		500	23.26	83.74	52.03
	600	11.74	42.26	26.26		600	24.37	87.73	54.51
	700	12.02	43.27	26.89		700	25.29	91.04	56.57
	800	12.24	44.06	27.38		800	26.06	93.82	58.30
	900	12.43	44.75	27.81		900	26.72	96.19	59.77
	1000	12.59	45.32	28.16		1000	27.30	98.28	61.07
	1200	12.84	46.22	28.72		1200	28.25	101.70	63.19
	1500	13.11	47.20	29.33		1500	29.34	105.62	65.63
	2000	13.41	48.28	30.00		2000	30.41	109.48	68.03
	3000	13.73	49.43	30.71		3000	32.10	115.56	71.81
	∞	14.48	52.13	32.39		∞	36.20	130.32	80.98

Latitude 35° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	15.34	55.22	34.31	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	18.22	65.59	40.76
	200	19.86	71.50	44.43		200	23.87	85.93	53.39
	300	22.77	81.97	50.93		300	27.59	99.32	61.71
	400	24.91	89.68	55.73		400	30.37	109.33	67.93
	500	26.57	95.65	59.43		500	32.57	117.25	72.86
	600	27.91	100.48	62.44		600	34.38	123.77	76.91
	700	29.04	104.54	64.96		700	35.91	129.28	80.33
	800	30.00	108.00	67.11		800	37.22	133.99	83.26
	900	30.82	110.95	68.94		900	38.37	138.13	85.83
	1000	31.55	113.58	70.58		1000	39.38	141.77	88.09
	1200	32.76	117.94	73.28		1200	41.10	147.96	91.94
	1500	34.15	122.94	76.39		1500	43.11	155.20	96.44
	2000	35.79	128.84	80.06		2000	45.54	163.94	101.87
	3000	37.76	135.94	84.47		3000	48.54	174.74	108.58
	∞	43.44	156.38	97.17		∞	57.92	208.51	129.56

Latitude 40°.

$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	2.11	7.60	4.72	$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	5.04	18.14	11.27
	200	2.30	8.28	5.14		200	5.90	21.24	13.20
	300	2.38	8.57	5.33		300	6.33	22.79	14.16
	400	2.43	8.75	5.44		400	6.60	23.76	14.76
	500	2.46	8.86	5.51		500	6.78	24.41	15.17
	600	2.48	8.93	5.55		600	6.91	24.88	15.46
	700	2.49	8.96	5.57		700	7.01	25.24	15.68
	800	2.50	9.00	5.59		800	7.08	25.49	15.84
	900	2.51	9.04	5.62		900	7.15	25.74	15.99
	1000	2.52	9.07	5.63		1000	7.20	25.92	16.11
	1200	2.53	9.11	5.66		1200	7.28	26.21	16.29
	1500	2.54	9.14	5.68		1500	7.37	26.53	16.49
	2000	2.55	9.18	5.70		2000	7.46	26.86	16.69
	3000	2.56	9.22	5.73		3000	7.55	27.18	16.89
	∞	2.58	9.29	5.77		∞	7.75	27.90	17.34
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	3.71	13.36	8.30	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	6.23	22.43	13.94
	200	4.22	15.19	9.44		200	7.41	26.68	16.58
	300	4.46	16.06	9.98		300	8.04	28.94	17.98
	400	4.61	16.60	10.31		400	8.44	30.38	18.88
	500	4.70	16.92	10.51		500	8.72	31.39	19.50
	600	4.77	17.17	10.67		600	8.92	32.11	19.95
	700	4.82	17.35	10.75		700	9.08	32.69	20.31
	800	4.85	17.46	10.85		800	9.21	33.16	20.60
	900	4.89	17.60	10.94		900	9.31	33.52	20.83
	1000	4.91	17.68	10.99		1000	9.40	33.84	21.03
	1200	4.95	17.82	11.07		1200	9.53	34.31	21.32
	1500	4.99	17.96	11.16		1500	9.67	34.81	21.63
	2000	5.03	18.11	11.25		2000	9.82	35.35	21.97
	3000	5.08	18.29	11.36		3000	10.09	36.32	22.57
	∞	5.17	18.61	11.56		∞	10.34	37.22	23.13

Latitude 40° (Continued).

$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	7.28	26.21	16.29	$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	13.34	48.02	29.84
	200	8.80	31.68	19.69		200	16.96	61.06	37.94
	300	9.63	34.67	21.54		300	19.20	69.12	42.95
	400	10.17	36.61	22.75		400	20.79	74.84	46.50
	500	10.55	37.98	23.60		500	21.99	79.16	49.19
	600	10.83	38.99	24.23		600	22.95	82.62	51.34
	700	11.06	39.82	24.74		700	23.73	85.43	53.08
	800	11.24	40.46	25.14		800	24.38	87.77	54.54
	900	11.39	41.00	25.48		900	24.94	89.78	55.79
	1000	11.51	41.44	25 75		1000	25.42	91.51	56.86
	1200	11.71	42.16	26.20		1200	26.20	94.32	58.66
	1500	11.91	42.88	26.64		1500	27.09	97.52	60.60
	2000	12.14	43.70	27.15		2000	28.09	101.12	62.83
	3000	12.38	45.57	28.32		3000	29.26	105.34	65.45
	∞	12.92	46.51	28.90		∞	32.30	116.28	72.25
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	9.60	34.56	21.47	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	14.95	53.82	33.44
	200	11.87	42.73	26.55		200	19.17	69.01	42.88
	300	13.19	47.48	29.50		300	21.83	78.59	48.83
	400	14.09	50.72	31.52		400	23.74	85.46	53.10
	500	14.74	53.06	32.97		500	25.21	90.76	56.40
	600	15.25	54.90	34.11		600	26.39	95.00	59.03
	700	15.65	56.34	35.01		700	27.36	98.50	61.21
	800	15.98	57.53	35.75		800	28.18	101.45	63.04
	900	16.25	58.50	36.35		900	28.88	103.97	64.60
	1000	16.48	59.33	36.87		1000	29.49	106.16	65.96
	1200	16.86	60.70	37.72		1200	30.50	109.80	68.23
	1500	17.26	62.14	38.61		1500	31.65	113.94	70.80
	2000	17.71	63.76	39.62		2000	32.97	118.69	73.75
	3000	18.21	65.56	40.74		3000	34.50	124.20	77.17
	∞	19.38	69.77	43.35		∞	38.77	139.57	86.72
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	11.57	41.65	25.88	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	17.82	64.15	39.86
	200	14.55	52.38	32.55		200	23.14	83.30	51.76
	300	16.35	58.86	36.57		300	26.58	95.69	59.46
	400	17.60	63.36	39.37		400	29.11	104.80	65.12
	500	18.52	66.67	41.43		500	31.08	111.89	69.53
	600	19.26	69.34	43.09		600	32.69	117.68	73.12
	700	19.84	71.42	44.38		700	34.04	122.54	76.14
	800	20.33	73.19	45.48		800	35.18	126.65	78.70
	900	20.74	74.66	46.39		900	36.18	130.25	80.93
	1000	21.10	75.96	47.20		1000	37.05	133.38	82.88
	1200	21.67	78.01	48.47		1200	38.50	138.60	86.12
	1500	22.31	80.32	49.91		1500	40.20	144.72	89.93
	2000	23.02	82.87	51.49		2000	42.19	151.88	94.37
	3000	23.83	85.79	53.31		3000	44.60	160.56	99.86
	∞	25.84	93.02	57.80		∞	51.69	186.08	115.62

Latitude 45°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	1.97	7.09	4.41	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	5.96	21.46	12.87
	200	2.13	7.67	4.77		200	7.01	25.24	15.68
	300	2.19	7.88	4.90		300	7.55	27.18	16.89
	400	2.23	8.03	4.99		400	7.89	28.40	17.42
	500	2.25	8.10	5.03		500	8.12	29.23	18.16
	600	2.27	8.17	5.08		600	8.29	29.84	18.54
	700	2.28	8.21	5.10		700	8.42	30.31	18.83
	800	2.29	8.24	5.12		800	8.52	30.67	19.06
	900	2.29	8.24	5.12		900	8.60	30.96	19.24
	1000	2.30	8.28	5.14		1000	8.67	31.21	19.39
	1200	2.31	8.32	5.17		1200	8.78	31.61	19.64
	1500	2.32	8.35	5.19		1500	8.89	32.00	19.84
	2000	2.33	8.39	5.21		2000	9.01	32.44	20.16
	3000	2.33	8.39	5.21		3000	9.14	32.90	20.44
	∞	2.35	8.46	5.26		∞	9.40	33.84	21.03
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	3.52	12.67	7.87	$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	7.40	26.64	16.55
	200	3.94	14.18	8.81		200	8.36	30.10	18.70
	300	4.14	14.90	9.26		300	9.08	32.69	20.31
	400	4.26	15.34	9.53		400	9.54	34.34	21.34
	500	4.33	15.59	9.69		500	9.86	35.50	22.06
	600	4.39	15.80	9.82		600	10.10	36.36	22.59
	700	4.43	15.95	9.91		700	10.28	37.01	23.00
	800	4.46	16.06	9.98		800	10.43	37.55	23.33
	900	4.49	16.16	10.04		900	10.55	37.98	23.60
	1000	4.50	16.20	10.07		1000	10.65	38.34	23.82
	1200	4.53	16.31	10.13		1200	10.80	38.88	24.16
	1500	4.56	16.42	10.20		1500	10.97	39.49	24.54
	2000	4.60	16.56	10.29		2000	11.15	40.14	24.94
	3000	4.63	16.57	10.36		3000	11.33	40.79	25.35
	∞	4.70	16.92	10.51		∞	11.75	42.30	26.28
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	4.81	17.32	10.76	$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	9.28	33.41	20.72
	200	5.55	19.98	12.42		200	11.36	40.90	25.41
	300	5.92	21.31	13.24		300	12.54	45.14	28.05
	400	6.13	22.07	13.71		400	13.32	47.95	29.79
	500	6.28	22.61	14.05		500	13.88	49.97	31.05
	600	6.39	23.00	14.29		600	14.31	51.52	32.01
	700	6.47	23.29	14.47		700	14.65	52.74	32.77
	800	6.53	23.51	14.61		800	14.92	53.71	33.37
	900	6.58	23.69	14.72		900	15.15	54.54	33.89
	1000	6.62	23.83	14.81		1000	15.34	55.22	34.31
	1200	6.69	24.08	14.96		1200	15.64	56.30	34.98
	1500	6.75	24.30	15.10		1500	15.97	57.49	35.72
	2000	6.82	24.55	15.25		2000	16.33	58.79	36.53
	3000	6.90	24.84	15.43		3000	16.72	60.19	37.40
	∞	7.05	25.38	15.77		∞	17.62	63.43	39.41

Latitude 45° (Continued).

$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$	$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	11.24	40.46	25.14	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	14.59	52.52	32.63
	200	14.00	50.40	31.32		200	18.55	66.78	41.50
	300	15.61	56.20	34.92		300	21.00	75.60	46.98
	400	16.72	60.19	37.40		400	22.72	81.79	50.82
	500	17.53	63.11	39.21		500	24.04	86.54	53.77
	600	18.16	65.38	40.62		600	25.08	90.29	56.10
	700	18.67	67.21	41.76		700	25.93	93.35	58.00
	800	19.08	68.69	42.68		800	26.64	95.90	59.59
	900	19.43	69.95	43.47		900	27.24	98.06	60.93
	1000	19.72	70.99	44.11		1000	27.77	99.97	62.12
	1200	20.20	72.72	45.23		1200	28.62	103.03	64.02
	1500	20.72	74.59	46.35		1500	29.58	106.49	66.17
	2000	21.30	76.68	46.78		2000	30.68	110.45	68.63
	3000	21.94	78.98	49.08		3000	31.94	114.98	71.45
	∞	23.49	84.56	52.54		∞	35.24	126.86	78.83
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	12.99	46.76	29.05	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	17.45	62.82	39.03
	200	16.37	58.93	36.62		200	22.48	80.93	50.29
	300	18.41	66.28	41.18		300	25.68	92.45	57.45
	400	19.83	71.37	44.35		400	27.99	100.76	62.61
	500	20.90	75.24	46.75		500	29.78	107.21	66.62
	600	21.74	78.26	48.63		600	31.23	112.43	69.86
	700	22.41	80.68	50.13		700	32.42	116.71	72.52
	800	22.97	82.69	51.38		800	33.44	120.38	74.80
	900	23.44	84.38	52.43		900	34.31	123.52	76.75
	1000	23.85	85.86	53.35		1000	35.06	126.22	78.43
	1200	24.51	88.24	54.83		1200	36.32	130.75	81.25
	1500	25.25	90.90	56.48		1500	37.77	135.97	84.49
	2000	26.07	93.85	58.32		2000	39.45	142.02	88.25
	3000	27.01	97.24	60.42		3000	41.43	149.15	92.68
	∞	29.37	105.73	65.70		∞	46.99	169.16	105.11

Latitude 50°.

$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	1.86	6.70	4.16	$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	3.34	12.02	7.47
	200	1.99	7.16	4.45		200	3.72	13.39	8.32
	300	2.04	7.34	4.56		300	3.89	14.00	8.70
	400	2.07	7.45	4.63		400	3.98	14.33	8.90
	500	2.09	7.52	4.67		500	4.04	14.54	9.04
	600	2.10	7.56	4.70		600	4.09	14.72	9.15
	700	2.11	7.60	4.72		700	4.12	14.83	9.22
	800	2.12	7.63	4.74		800	4.15	14.94	9.28
	900	2.13	7.67	4.77		900	4.17	15.01	9.33
	1000	2.13	7.67	4.77		1000	4.18	15.05	9.35
	1200	2.14	7.70	4.79		1200	4.21	15.16	9.42
	1500	2.14	7.70	4.79		1500	4.23	15.23	9.46
	2000	2.15	7.74	4.81		2000	4.26	15.34	9.53
	3000	2.15	7.74	4.81		3000	4.28	15.41	9.59
	∞	2.17	7.81	4.85		∞	4.34	15.62	9.71

Latitude 50° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	4.61	16.60	10.31	$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	9.01	32.44	20.16
	200	5.27	18.97	11.79		200	10.92	39.31	24.43
	300	5.58	20.09	12.48		300	11.98	43.13	26.80
	400	5.76	20.74	12.89		400	12.67	45.61	28.34
	500	5.89	21.20	13.17		500	13.16	47.38	29.44
	600	5.97	21.49	13.35		600	13.53	48.71	30.27
	700	6.04	21.74	13.51		700	13.82	49.75	30.91
	800	6.09	21.92	13.62		800	14.06	50.62	31.45
	900	6.13	22.07	13.71		900	14.25	51.30	31.88
	1000	6.17	22.21	13.80		1000	14.41	51.88	32.24
	1200	6.22	22.39	13.91		1200	14.66	52.78	32.80
	1500	6.27	22.57	14.02		1500	14.93	53.75	33.40
	2000	6.33	22.79	14.16		2000	15.23	54.83	34.07
	3000	6.38	22.97	14.27		3000	15.54	55.94	34.76
	∞	6.51	23.44	14.57		∞	16.26	58.54	36.38
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	5.73	20.63	12.82	$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	10.95	39.42	24.49
	200	6.68	24.05	14.94		200	13.51	48.64	30.22
	300	7.15	25.74	15.99		300	14.99	53.96	33.53
	400	7.44	26.78	16.64		400	15.98	57.53	35.75
	500	7.63	27.47	17.07		500	16.70	60.12	37.36
	600	7.77	27.97	17.38		600	17.25	62.10	38.59
	700	7.88	28.37	17.63		700	17.69	63.68	39.57
	800	7.97	28.69	17.83		800	18.04	64.94	40.35
	900	8.03	28.91	17.96		900	18.34	66.02	41.02
	1000	8.09	29.12	18.09		1000	18.59	66.92	41.58
	1200	8.18	29.45	18.30		1200	18.99	68.36	42.48
	1500	8.27	29.77	18.50		1500	19.43	69.95	43.47
	2000	8.36	30.10	18.70		2000	19.91	71.68	44.54
	3000	8.46	30.46	18.93		3000	20.44	73.58	45.72
	∞	8.67	31.21	19.39		∞	21.69	78.08	48.52
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	6.76	24.34	15.12	$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	12.69	45.68	28.38
	200	7.99	28.76	17.87		200	15.86	57.10	35.48
	300	8.63	31.07	19.31		300	17.73	63.83	39.66
	400	9.02	32.47	20.18		400	19.02	68.47	42.55
	500	9.29	33.44	20.78		500	19.97	71.89	44.67
	600	9.50	34.20	21.25		600	20.71	74.56	46.33
	700	9.65	34.74	21.59		700	21.30	76.68	47.65
	800	9.77	35.17	21.85		800	21.79	78.44	48.74
	900	9.87	35.53	22.08		900	22.21	79.96	49.68
	1000	9.96	35.86	22.28		1000	22.55	81.18	50.44
	1200	10.09	36.32	22.57		1200	23.12	83.23	51.72
	1500	10.22	36.79	22.86		1500	23.74	85.46	53.10
	2000	10.36	37.30	23.18		2000	24.47	88.09	54.74
	3000	10.52	37.87	23.53		3000	25.21	90.76	56.40
	∞	10.84	39.02	24.25		∞	27.11	97.60	60.65

Latitude 50° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	14.28	51.41	31.95	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	17.12	61.63	38.29
	200	18.01	64.84	40.29		200	21.90	78.84	48.99
	300	20.27	72.97	45.34		300	24.89	89.60	55.67
	400	21.85	78.66	48.88		400	27.03	97.31	60.47
	500	23.03	82.91	51.52		500	28.66	103.18	64.11
	600	23.96	86.26	53.60		600	29.97	107.89	67.04
	700	24.72	88.99	55.30		700	31.04	111.74	69.43
	800	25.34	91.22	56.68		800	31.95	115.02	71.47
	900	25.87	93.13	57.87		900	32.72	117.79	73.19
	1000	26.33	94.79	58.90		1000	33.39	120.20	74.69
	1200	27.07	97.45	60.55		1200	34.50	124.20	77.17
	1500	27.89	100.40	62.39		1500	35.75	128.70	79.97
	2000	28.81	103.72	64.45		2000	37.19	133.88	83.19
	3000	29.86	107.50	66.80		3000	38.87	139.93	86.95
	∞	32.53	117.11	72.77		∞	43.37	156.13	97.01

Latitude 55°.

$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	100	1.77	6.37	3.96	$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	100	4.44	15.98	9.93
	200	1.88	6.77	4.21		200	5.03	18.11	11.25
	300	1.93	6.95	4.32		300	5.30	19.08	11.86
	400	1.95	7.02	4.36		400	5.46	19.66	12.22
	500	1.96	7.06	4.39		500	5.57	20.05	12.46
	600	1.97	7.09	4.41		600	5.64	20.30	12.61
	700	1.98	7.13	4.43		700	5.70	20.52	12.75
	800	1.99	7.16	4.45		800	5.74	20.66	12.84
	900	1.99	7.16	4.45		900	5.77	20.77	12.91
	1000	1.99	7.16	4.45		1000	5.80	20.88	12.97
	1200	2.00	7.20	4.47		1200	5.85	21.06	13.09
	1500	2.00	7.20	4.47		1500	5.89	21.20	13.17
	2000	2.01	7.24	4.50		2000	5.94	21.38	13.29
	3000	2.02	7.27	4.52		3000	5.99	21.56	13.40
	∞	2.03	7.31	4.54		∞	6.08	21.89	13.60
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	100	3.20	11.52	7.16	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	100	5.54	19.94	12.39
	200	3.53	12.71	7.90		200	6.40	23.04	14.32
	300	3.68	13.25	8.23		300	6.82	24.55	15.25
	400	3.76	13.54	8.41		400	7.07	25.45	15.81
	500	3.81	13.72	8.53		500	7.24	26.06	16.19
	600	3.85	13.86	8.61		600	7.36	26.50	16.47
	700	3.88	13.97	8.68		700	7.45	26.82	16.67
	800	3.90	14.04	8.72		800	7.52	27.07	16.82
	900	3.91	14.08	8.75		900	7.58	27.29	16.96
	1000	3.93	14.15	8.79		1000	7.63	27.47	17.07
	1200	3.95	14.22	8.84		1200	7.70	27.72	17.22
	1500	3.97	14.29	8.88		1500	7.77	27.97	17.38
	2000	3.99	14.36	8.92		2000	7.85	38.26	17.56
	3000	4.01	14.44	8.97		3000	7.94	28.58	17.76
	∞	4.06	14.62	9.08		∞	8.11	29.20	18.14

Latitude 55° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	100	6.55	23.58	14.65	$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	12.43	44.75	27.81
	200	7.68	27.65	17.18		200	15.41	55.48	34.47
	300	8.24	29.66	18.43		300	17.15	61.74	38.36
	400	8.59	30.92	19.21		400	18.22	65.59	40.76
	500	8.83	31.79	19.75		500	19.19	69.08	42.92
	600	9.01	32.44	20.16		600	19.85	71.46	44.40
	700	9.14	32.90	20.44		700	20.38	73.37	45.59
	800	9.25	33.30	20.69		800	20.82	74.95	46.57
	900	9.33	33.59	20.87		900	21.18	76.25	47.38
	1000	9.40	33.84	21.03		1000	21.49	77.36	48.07
	1200	9.51	34.24	21.28		1200	21.98	79.13	49.17
	1500	9.63	34.67	21.54		1500	22.52	81.07	50.37
	2000	9.74	35.06	21.79		2000	23.12	83.23	51.72
	3000	9.87	35.53	22.08		3000	23.77	85.57	53.17
	∞	10.14	36.50	22.68		∞	25.35	91.26	56.71
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	100	8.77	31.57	19.62	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	14.00	50.40	31.32
	200	10.55	37.98	23.60		200	17.54	63.14	39.23
	300	11.51	41.44	25.75		300	19.65	70.74	43.96
	400	12.13	43.67	27.14		400	21.00	75.60	46.98
	500	12.56	45.22	28.10		500	22.18	79.85	49.62
	600	12.89	46.40	28.83		600	23.03	82.91	51.52
	700	13.14	47.30	29.39		700	23.70	85.32	53.02
	800	13.35	48.06	29.86		800	24.26	87.34	54.27
	900	13.51	48.64	30.22		900	24.73	89.03	55.32
	1000	13.65	49.14	30.53		1000	25.13	90.47	56.22
	1200	13.87	49.93	31.03		1200	25.79	92.84	57.69
	1500	14.10	50.76	31.56		1500	26.50	95.40	59.28
	2000	14.35	51.66	32.10		2000	27.30	98.28	61.07
	3000	14.62	52.63	32.70		3000	28.20	101.52	63.08
	∞	15.21	54.76	34.03		∞	30.42	109.51	68.05
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	10.70	38.52	23.94	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	16.84	60.62	37.67
	200	13.10	47.16	29.30		200	21.40	77.04	47.87
	300	14.45	52.02	32.32		300	24.21	87.16	54.16
	400	15.35	55.26	34.34		400	26.10	93.96	58.38
	500	16.00	57.60	35.79		500	27.70	99.72	61.96
	600	16.48	59.33	36.87		600	28.91	104.08	64.67
	700	16.88	60.77	37.76		700	29.88	107.57	66.84
	800	17.19	61.88	38.45		800	30.70	110.52	68.67
	900	17.45	62.82	39.03		900	31.39	113.00	70.22
	1000	17.67	63.61	39.53		1000	31.99	115.16	71.56
	1200	18.02	64.87	40.31		1200	32.95	118.62	73.70
	1500	18.39	66.20	41.14		1500	34.08	122.69	76.24
	2000	18.80	67.68	42.05		2000	35.34	127.22	79.05
	3000	19.25	69.30	43.06		3000	36.79	132.44	82.29
	∞	20.28	73.01	45.37		∞	40.56	146.02	90.73

Latitude 60°.

$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B \text{ (mm.)}}{100 \text{ km.}}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{789 \text{ mi.}}$	100	1.69	6.08	3.78	$\frac{0.8 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{197 \text{ mi.}}$	100	5.38	19.37	12.04
	200	1.79	6.44	4.00		200	6.17	22.21	13.80
	300	1.83	6.59	4.10		300	6.54	23.54	14.63
	400	1.85	6.66	4.14		400	6.77	24.37	15.14
	500	1.86	6.70	4.16		500	6.92	24.91	15.48
	600	1.87	6.73	4.18		600	7.02	25.27	15.70
	700	1.88	6.77	4.21		700	7.10	25.56	15.88
	800	1.88	6.77	4.21		800	7.17	25.81	16.04
	900	1.89	6.80	4.23		900	7.22	25.99	16.15
	1000	1.89	6.80	4.23		1000	7.26	26.14	16.24
	1200	1.90	6.84	4.25		1200	7.32	26.35	16.37
	1500	1.90	6.84	4.25		1500	7.38	26.57	16.51
	2000	1.90	6.84	4.25		2000	7.45	26.82	16.67
	3000	1.91	6.88	4.28		3000	7.53	27.11	16.85
	∞	1.91	6.88	4.28		∞	7.60	27.36	17.00
$\frac{0.4 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{395 \text{ mi.}}$	100	3.08	11.09	6.89	$\frac{1.0 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{158 \text{ mi.}}$	100	6.37	22.93	14.25
	200	3.38	12.17	7.56		200	7.42	26.71	16.60
	300	3.51	12.64	7.85		300	7.93	28.55	17.74
	400	3.58	12.89	8.01		400	8.25	29.70	18.45
	500	3.63	13.07	8.12		500	8.46	30.46	18.92
	600	3.66	13.18	8.19		600	8.61	31.00	19.26
	700	3.68	13.25	8.23		700	8.73	31.43	19.53
	800	3.70	13.32	8.28		800	8.82	31.75	19.73
	900	3.72	13.39	8.32		900	8.90	32.04	19.91
	1000	3.73	13.43	8.34		1000	8.96	32.26	20.05
	1200	3.74	13.46	8.36		1200	9.05	32.58	20.24
	1500	3.76	13.54	8.41		1500	9.15	32.94	20.47
	2000	3.78	13.61	8.46		2000	9.25	33.30	20.69
	3000	3.80	13.68	8.50		3000	9.37	33.73	20.96
	∞	3.80	13.68	8.50		∞	9.50	34.20	21.25
$\frac{0.6 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{263 \text{ mi.}}$	100	4.29	15.44	9.59	$\frac{1.5 \text{ mm.}}{100 \text{ km.}} = \frac{0.1 \text{ in.}}{105 \text{ mi.}}$	100	8.57	30.85	19.17
	200	4.83	17.39	10.81		200	10.24	36.86	22.90
	300	5.07	18.25	11.34		300	11.12	40.03	24.87
	400	5.22	18.79	11.68		400	11.68	42.05	26.13
	500	5.31	19.12	11.88		500	12.08	43.49	27.02
	600	5.37	19.33	12.04		600	12.37	44.53	27.67
	700	5.42	19.51	12.12		700	12.59	45.32	28.16
	800	5.46	19.66	12.22		800	12.77	45.97	28.56
	900	5.49	19.76	12.28		900	12.92	46.51	28.90
	1000	5.51	19.84	12.33		1000	13.05	46.98	29.19
	1200	5.55	19.98	12.42		1200	13.23	47.63	29.60
	1500	5.59	20.12	12.50		1500	13.44	48.38	30.06
	2000	5.63	20.27	12.59		2000	13.65	49.14	30.53
	3000	5.67	20.41	12.68		3000	13.88	49.97	31.05
	∞	5.70	20.52	12.85		∞	14.25	51.30	31.88

Latitude 60° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	100	10.48	37.73	23.44	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	100	14.77	53.17	33.04
	200	12.75	45.90	28.52		200	17.14	61.70	38.34
	300	14.01	50.44	31.34		300	19.12	68.83	42.77
	400	14.83	53.39	33.17		400	20.48	73.73	45.81
	500	15.42	55.51	34.49		500	21.47	77.29	48.03
	600	15.86	57.10	35.48		600	22.24	80.06	49.75
	700	16.21	58.36	36.26		700	22.86	82.30	51.14
	800	16.49	59.36	36.88		800	23.36	84.10	52.26
	900	16.72	60.19	37.40		900	23.79	85.64	53.22
	1000	16.92	60.91	37.85		1000	24.15	86.94	54.02
	1200	17.22	61.99	38.52		1200	24.73	89.03	55.32
	1500	17.56	63.22	39.28		1500	25.38	91.37	56.77
	2000	17.92	64.51	40.08		2000	26.08	93.89	58.34
	3000	18.30	65.88	40.94		3000	26.87	96.73	60.10
	∞	18.99	68.36	42.48		∞	28.49	102.56	63.73
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	100	12.20	43.92	27.29	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	100	16.59	59.72	37.11
	200	15.03	54.11	33.62		200	20.96	75.46	46.89
	300	16.66	59.98	37.27		300	23.63	85.07	52.86
	400	17.75	63.90	39.71		400	25.00	91.80	57.04
	500	18.54	66.74	41.47		500	26.90	96.84	60.17
	600	19.14	68.90	42.81		600	28.01	100.84	62.66
	700	19.62	70.63	43.89		700	28.91	104.08	64.67
	800	20.01	72.04	44.76		800	29.66	106.78	66.35
	900	20.34	73.22	45.50		900	30.29	109.04	67.76
	1000	20.61	74.20	46.10		1000	30.84	111.02	68.98
	1200	21.05	75.78	47.09		1200	31.73	114.23	70.98
	1500	21.53	77.51	48.16		1500	32.72	117.79	73.19
	2000	22.05	79.38	49.32		2000	33.83	121.79	75.68
	3000	22.63	81.47	50.62		3000	35.11	126.40	78.54
	∞	23.74	85.46	53.10		∞	37.98	136.73	84.96

TABLE II.

Gradient Wind Velocity for Anticyclonic Movement.

Latitude 25°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	255.1	7.86	28.30	17.59
	300	5.67	20.41	12.68
	400	4.91	17.68	10.99
	500	4.63	16.67	10.36
	600	4.47	16.09	10.00
	700	4.38	15.77	9.80
	800	4.31	15.52	9.64
	900	4.26	15.34	9.53
	1000	4.22	15.19	9.44
	1200	4.17	15.01	9.33
	1500	4.11	14.78	9.18
	2000	4.07	14.65	9.10
	3000	4.02	14.47	8.99
	∞	3.93	14.15	8.79
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	510.2	15.72	56.59	35.16
	600	11.34	40.82	25.36
	700	10.34	37.22	23.13
	800	9.82	35.35	21.97
	900	9.48	34.13	21.21
	1000	9.25	33.30	20.69
	1200	8.94	32.18	20.00
	1500	8.68	31.25	19.42
	2000	8.44	30.38	18.88
	3000	8.23	29.63	18.41
	∞	7.86	28.30	17.58
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	765.3	23.58	84.89	52.75
	800	19.52	70.27	43.66
	900	17.01	61.24	38.05
	1000	15.89	57.20	35.54
	1200	14.72	52.99	32.93
	1500	13.87	49.93	31.03
	2000	13.21	47.56	29.55
	3000	12.66	45.58	28.32
	∞	11.79	42.44	26.37
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	1020.4	31.44	113.18	70.33
	1200	22.67	81.61	50.71
	1500	20.09	72.32	44.94
	2000	18.50	66.60	41.38
	3000	17.35	62.46	38.81
	∞	15.72	56.59	35.16
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	1275.5	39.30	141.48	87.91
	1500	28.34	102.02	63.39
	2000	24.54	88.34	54.89
	3000	22.36	80.50	50.02
	∞	19.65	70.74	43.96
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	1913.3	58.96	212.26	131.89
	2000	48.80	175.68	109.16
	3000	36.81	132.52	82.34
	∞	29.48	106.13	65.95
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	2551	78.62	283.03	175.87
	3000	56.68	204.05	126.79
	∞	39.31	141.52	87.94

Latitude 30°.

$\frac{\triangle B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	182.25	6.64	23.90	14.85
	200	5.12	18.43	11.45
	300	4.08	14.69	9.13
	400	3.82	13.75	8.54
	500	3.70	13.32	8.28
	600	3.62	13.03	8.10
	700	3.57	12.85	7.98
	800	3.54	12.74	7.92
	900	3.51	12.64	7.85
	1000	3.49	12.56	7.80
	1200	3.46	12.46	7.74
	1500	3.43	12.35	7.67
	2000	3.40	12.24	7.61
	3000	3.38	12.17	7.56
	∞	3.32	11.95	7.43
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	364.5	13.28	47.81	29.71
	400	10.24	36.86	22.90
	500	8.74	31.46	19.55
	600	8.17	29.41	18.27
	700	7.85	28.26	17.56
	800	7.65	27.54	17.11
	900	7.50	27.00	16.78
	1000	7.40	26.64	16.55
	1200	7.24	26.06	16.19
	1500	7.11	25.60	15.91
	2000	6.98	25.13	15.62
	3000	6.86	24.70	15.35
	∞	6.64	23.90	14.85
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	546.75	19.94	71.78	44.60
	600	15.36	55.30	34.36
	700	13.58	48.89	30.38
	800	12.76	45.94	28.55
	900	12.26	44.14	27.43
	1000	11.91	42.88	26.64
	1200	11.49	41.36	25.70
	1500	11.09	39.92	24.81
	2000	10.76	38.74	24.07
	3000	10.47	37.69	23.42
	∞	9.97	35.89	22.30
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	729	26.58	95.69	59.46
	800	20.48	73.73	45.81
	900	18.51	66.64	41.41
	1000	17.48	62.93	39.10
	1200	16.34	58.82	36.55
	1500	15.48	55.73	34.63
	2000	14.79	53.24	33.08
	3000	14.21	51.16	31.79
	∞	13.29	47.84	29.73
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	911.25	33.22	119.59	74.31
	1000	25.60	92.16	57.26
	1200	22.29	80.24	49.86
	1500	20.43	73.55	45.70
	2000	19.12	68.83	42.77
	3000	18.11	65.20	40.51
	∞	16.61	59.80	37.16
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	1367.9	48.84	179.42	111.49
	1500	38.40	138.24	85.90
	2000	31.89	114.80	71.33
	3000	28.68	103.25	64.16
	∞	24.92	89.71	55.74
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	1822.5	66.44	239.18	148.62
	2000	51.20	184.32	114.53
	3000	40.85	147.06	95.76
	∞	33.22	119.59	74.31
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	2278.1	83.06	299.02	185.80
	3000	55.72	200.59	124.64
	∞	41.53	149.51	92.90
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	2733.8	99.68	358.85	222.98
	3000	76.79	276.44	171.77
	∞	49.84	179.42	111.49

Latitude 35°.

$\frac{\Delta B\ (\text{mm.})}{100\ \text{km.}}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$
$\frac{0.2\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{789\ \text{mi.}}$	138.5	5.80	20.88	12.88
	200	3.73	13.43	8.35
	300	3.34	12.02	7.47
	400	3.20	11.52	7.16
	500	3.13	11.27	7.00
	600	3.09	11.12	6.91
	700	3.06	11.02	6.85
	800	3.03	10.91	6.78
	900	3.02	10.87	6.75
	1000	3.00	10.80	6.71
	1200	2.98	10.73	6.67
	1500	2.97	10.69	6.64
	2000	2.95	10.62	6.60
	3000	2.93	10.55	6.56
	∞	2.90	10.44	6.49
$\frac{0.4\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{395\ \text{mi.}}$	277.0	11.58	41.69	25.90
	300	9.07	32.65	20.30
	400	7.46	26.86	16.61
	500	6.95	25.02	15.55
	600	6.68	24.05	14.94
	700	6.52	23.47	14.58
	800	6.41	23.08	14.34
	900	6.32	22.75	14.14
	1000	6.26	22.54	14.01
	1200	6.17	22.21	13.80
	1500	6.09	21.92	13.62
	2000	6.01	21.64	13.45
	3000	5.93	21.35	13.27
	∞	5.79	20.84	12.95
$\frac{0.6\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{263\ \text{mi.}}$	415.5	17.38	62.57	38.88
	500	12.31	44.32	27.54
	600	11.18	40.25	25.01
	700	10.61	38.20	23.74
	800	10.26	36.94	22.95
	900	10.02	36.07	22.41
	1000	9.85	35.46	22.03
	1200	9.61	34.60	21.50
	1500	9.39	33.80	21.00
	2000	9.19	33.08	20.56
	3000	9.01	32.44	20.16
	∞	8.69	31.28	19.48
$\frac{0.8\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{197\ \text{mi.}}$	554.0	23.16	83.38	51.81
	600	18.14	65.30	40.58
	700	15.91	57.28	35.59
	800	14.90	53.64	33.33
	900	14.30	51.48	31.99
	1000	13.89	50.00	31.07
	1200	13.36	48.10	29.89
$\frac{0.8\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{197\ \text{mi.}}$	1500	12.92	46.51	28.90
	2000	12.52	45.07	28.01
	3000	12.17	43.81	27.22
	∞	11.58	41.69	25.90
$\frac{1.0\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{158\ \text{mi.}}$	692.5	28.96	104.26	64.78
	700	26.24	94.46	58.70
	800	21.19	76.28	47.40
	900	19.57	70.45	43.78
	1000	18.63	67.07	41.68
	1200	17.55	63.18	39.26
	1500	16.71	60.16	37.38
	2000	16.01	57.64	35.82
	3000	15.43	55.55	34.52
	∞	14.48	52.13	32.39
$\frac{1.5\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{105\ \text{mi.}}$	1038.7	43.44	156.38	97.15
	1200	31.79	114.44	71.11
	1500	27.95	100.62	62.52
	2000	25.66	92.38	57.40
	3000	24.02	86.47	53.73
	∞	21.72	78.19	48.58
$\frac{2.0\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{79\ \text{mi.}}$	1385.0	57.92	208.51	129.56
	1500	45.36	163.30	101.47
	2000	37.26	134.14	83.33
	3000	33.41	120.28	74.70
	∞	28.96	104.26	64.78
$\frac{2.5\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{63\ \text{mi.}}$	1731.2	72.40	260.64	161.95
	2000	52.98	190.73	118.51
	3000	43.87	157.93	98.13
	∞	36.20	130.32	80.98
$\frac{3.0\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{53\ \text{mi.}}$	2077.5	86.88	312.77	194.35
	3000	55.89	201.20	125.02
	∞	43.44	156.38	97.17
$\frac{4.0\ \text{mm.}}{100\ \text{km.}} = \frac{0.1\ \text{in.}}{39\ \text{mi.}}$	2770.0	115.84	417.02	259.12
	3000	90.72	326.59	202.93
	∞	57.92	208.51	129.56

Latitude 40°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V \frac{m}{s}$	$V \frac{km}{hr}$	$V \frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	110.25	5.16	18.58	11.55
	200	3.10	11.16	6.93
	300	2.88	10.37	6.44
	400	2.79	10.04	6.24
	500	2.74	9.86	6.13
	600	2.72	9.79	6.08
	700	2.70	9.72	6.04
	800	2.68	9.65	6.00
	900	2.67	9.61	5.97
	1000	2.66	9.58	5.95
	1200	2.65	9.54	5.93
	1500	2.63	9.47	5.88
	2000	2.62	9.43	5.86
	3000	2.61	9.40	5.84
	∞	2.58	9.29	5.77
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	220.5	10.34	37.22	23.13
	300	6.83	24.59	15.28
	400	6.19	22.28	13.84
	500	5.92	21.31	13.24
	600	5.76	20.74	12.89
	700	5.66	20.38	12.66
	800	5.59	20.12	12.50
	900	5.53	19.91	12.37
	1000	5.49	19.76	12.28
	1200	5.43	19.55	12.15
	1500	5.37	19.33	12.01
	2000	5.32	19.15	11.90
	3000	5.27	18.97	11.79
	∞	5.17	18.61	11.56
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	330.75	15.50	55.80	34.67
	400	10.95	39.42	24.50
	500	9.80	35.28	21.92
	600	9.29	33.44	20.78
	700	8.98	32.33	20.09
	800	8.78	31.61	19.64
	900	8.64	31.10	19.32
	1000	8.53	30.71	19.08
	1200	8.38	30.17	18.79
	1500	8.23	29.63	18.41
	2000	8.10	29.16	18.12
	3000	7.98	28.73	17.85
	∞	7.75	27.90	17.34
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	441.0	20.68	74.45	46.26
	500	15.39	55.40	34.42
	600	13.65	49.14	30.53
	700	12.86	46.30	28.77
	800	12.38	44.57	27.69
	900	12.06	43.42	26.98
	1000	11.83	42.59	26.46
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	1200	11.52	41.47	25.77
	1500	11.24	40.46	25.14
	2000	10.98	39.53	24.56
	3000	10.75	58.70	24.05
	∞	10.34	37.22	23.13
$\frac{1.0\ mm.}{100\ km.} = \frac{1.0\ in.}{158\ mi.}$	551.25	25.84	93.02	57.80
	600	20.12	72.43	45.01
	700	17.69	63.68	39.57
	800	16.59	59.72	37.11
	900	15.93	57.35	35.64
	1000	15.48	55.73	34.63
	1200	14.89	53.60	33.31
	1500	14.39	51.80	32.19
	2000	13.96	50.26	31.23
	3000	13.58	48.89	30.38
	∞	12.92	46.51	28.90
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	826.9	38.76	139.54	86.71
	900	30.18	108.65	67.51
	1000	27.38	98.57	61.25
	1200	24.89	89.60	55.68
	1500	23.22	83.59	51.94
	2000	21.95	79.02	49.10
	3000	20.94	75.38	46.84
	∞	19.38	69.77	43.35
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	1102.5	51.68	186.05	115.61
	1200	40.23	144.83	89.99
	1500	34.13	122.87	76.35
	2000	30.96	111.46	69.26
	3000	29.77	107.17	66.59
	∞	25.84	93.02	57.80
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	1378.1	64.60	232.56	144.50
	1500	50.29	181.04	112.50
	2000	41.48	149.33	92.79
	3000	37.23	134.03	83.28
	∞	32.30	116.28	72.25
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	1653.75	77.54	279.14	173.45
	2000	54.76	197.14	122.50
	3000	46.43	167.15	103.86
	∞	38.77	139.57	86.72
$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	2205.0	103.38	372.17	231.25
	3000	68.25	245.70	152.67
	∞	51.69	186.08	115.62

Latitude 45°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	91.33	4.70	16.92	10.51
	100	3.62	13.03	8.10
	200	2.70	9.72	6.04
	300	2.56	9.22	5.73
	400	2.50	9.00	5.59
	500	2.47	8.89	5.52
	600	2.45	8.82	5.48
	700	2.43	8.75	5.44
	800	2.42	8.71	5.41
	900	2.41	8.68	5.39
	1000	2.41	8.68	5.39
	1200	2.40	8.64	5.37
	1500	2.39	8.60	5.34
	2000	2.38	8.57	5.33
	3000	2.36	8.50	5.28
	∞	2.35	8.46	5.26
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	182.66	9.40	33.84	21.03
	200	7.24	26.06	16.19
	300	5.78	20.81	12.93
	400	5.41	19.48	12.10
	500	5.23	18.83	11.70
	600	5.12	18.43	11.45
	700	5.05	18.18	11.30
	800	5.00	18.00	11.18
	900	4.97	17.89	11.12
	1000	4.94	17.78	11.05
	1200	4.89	17.60	10.94
	1500	4.85	17.46	10.85
	2000	4.81	17.32	10.76
	3000	4.77	17.17	10.67
	∞	4.70	16.92	10.51
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	274.0	14.10	50.76	31.54
	300	10.86	39.10	24.30
	400	9.02	32.47	20.18
	500	8.43	30.35	18.86
	600	8.11	29.20	18.14
	700	7.92	28.51	17.72
	800	7.78	28.01	17.40
	900	7.69	27.68	17.20
	1000	7.61	27.40	17.03
	1200	7.50	27.00	16.78
	1500	7.40	26.64	16.55
	2000	7.31	26.32	16.35
	3000	7.21	25.96	16.13
	∞	7.05	25.38	15.77

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	365.33	18.80	67.68	42.05
	400	14.48	52.13	32.39
	500	12.36	44.50	27.65
	600	11.55	41.58	25.84
	700	11.11	40.00	24.85
	800	10.82	38.95	24.20
	900	10.61	38.20	23.74
	1000	10.46	37.66	23.40
	1200	10.25	36.90	22.93
	1500	10.05	36.18	22.48
	2000	9.87	35.53	22.08
	3000	9.70	34.92	21.70
	∞	9.40	33.84	21.03
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	456.66	23.50	84.60	52.57
	500	18.10	65.16	40.49
	600	15.76	56.74	35.26
	700	14.77	53.17	33.04
	800	14.19	51.08	31.74
	900	13.80	49.68	30.87
	1000	13.52	48.67	30.24
	1200	13.14	47.30	29.39
	1500	12.81	46.12	28.66
	2000	12.50	45.00	27.96
	3000	12.23	44.03	27.36
	∞	11.75	42.30	26.28
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	685.0	35.24	126.86	78.83
	700	30.54	109.94	68.31
	800	25.50	91.80	57.04
	900	23.64	85.10	52.88
	1000	22.55	81.18	50.44
	1200	21.28	76.61	47.60
	1500	20.28	73.01	45.37
	2000	19.45	70.02	43.51
	3000	18.76	67.54	41.97
	∞	17.62	63.43	39.41
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	913.33	46.98	169.13	105.09
	1000	36.20	130.32	80.98
	1200	31.52	113.47	70.51
	1500	28.89	104.00	64.62
	2000	27.04	97.34	60.48
	3000	25.61	92.20	57.29
	∞	23.49	84.56	52.54
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	1141.66	58.74	211.46	131.39
	1200	47.93	172.55	107.22
	1500	39.40	141.84	88.14
	2000	35.46	127.66	79.32
	3000	32.86	118.30	73.51
	∞	29.37	105.73	65.70

Latitude 45° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	1370.0	70.48	253.73	157.66	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39.\ mi.}$	1826.66	93.98	338.33	210.23
	1500	54.30	195.48	121.46		2000	72.40	260.64	165.53
	2000	45.10	162.36	100.89		3000	57.77	207.97	129.23
	3000	40.56	146.02	90.73		∞	46.99	169.16	105.11
	∞	35.24	126.86	78.83					

Latitude 50°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	77.66	4.34	15.62	9.71
	100	2.94	10.58	6.57
	200	2.43	8.75	5.44
	300	2.33	8.39	5.21
	400	2.29	8.24	5.12
	500	2.26	8.14	5.06
	600	2.24	8.06	5.01
	700	2.23	8.03	4.99
	800	2.23	8.03	4.99
	900	2.22	7.99	4.96
	1000	2.21	7.96	4.95
	1200	2.21	7.96	4.95
	1500	2.20	7.92	4.92
	2000	2.19	7.88	4.90
	3000	2.19	7.88	4.90
	∞	2.17	7.81	4.85
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	155.33	8.68	31.25	19.42
	200	5.89	21.20	13.17
	300	5.12	18.43	11.45
	400	4.87	17.53	10.89
	500	4.74	17.06	10.60
	600	4.66	16.78	10.43
	700	4.61	16.60	10.31
	800	4.57	16.45	10.22
	900	4.54	16.34	10.15
	1000	4.52	16.27	10.11
	1200	4.49	16.16	10.04
	1500	4.46	16.06	9.98
	2000	4.42	15.91	9.89
	3000	4.40	15.84	9.84
	∞	4.34	15.62	9.71
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	233.0	13.02	46.87	29.12
	300	8.83	31.79	19.75
	400	7.90	28.44	17.67
	500	7.52	27.07	16.82
	600	7.30	26.28	16.33
	700	7.16	25.78	16.02
	800	7.06	25.42	15.80
	900	6.99	25.16	15.63
	1000	6.94	24.98	15.52
	1200	6.86	24.70	15.35

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.6\ mm.}{100\ km.}\ \frac{0.1\ in.}{263\ mi.}$	1500	6.78	24.41	15.17
	2000	6.71	24.16	15.01
	3000	6.64	23.90	14.85
	∞	6.51	23.44	14.57
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	310.66	17.34	62.42	38.79
	400	11.78	42.41	26.35
	500	10.74	38.66	24.04
	600	10.24	36.86	22.90
	700	9.94	35.78	22.23
	800	9.74	35.06	21.79
	900	9.59	34.52	21.45
	1000	9.48	34.13	21.21
	1200	9.31	33.52	20.83
	1500	9.18	33.05	20.54
	2000	9.04	32.54	20.22
	3000	8.91	32.08	19.93
	∞	8.67	31.21	19.39
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	388.33	21.68	78.05	48.50
	400	18.51	66.64	41.41
	500	14.72	52.99	32.93
	600	13.60	48.96	30.42
	700	13.01	46.84	29.11
	800	12.63	45.47	28.25
	900	12.36	44.50	27.65
	1000	12.17	43.81	27.22
	1200	11.90	42.84	26.62
	1500	11.65	41.94	26.06
	2000	11.43	41.15	25.57
	3000	11.24	40.46	25.14
	∞	10.84	39.02	24.25
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	582.5	32.52	117.07	72.75
	600	27.76	99.94	62.10
	700	23.07	83.05	51.60
	800	21.38	76.97	47.83
	900	20.41	73.48	45.66
	1000	19.76	71.14	44.20
	1200	18.94	68.18	42.36
	1500	18.25	65.70	40.82
	2000	17.66	63.58	39.51
	3000	17.14	61.70	38.34
	∞	16.26	58.54	36.38

Latitude 50° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	776.66	43.38	156.17	97.04	$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi}$	1165.0	65.06	234.22	145.54
	800	37.02	133.27	82.81		1200	55.53	199.91	124.22
	900	31.65	113.94	70.80		1500	44.17	159.01	98.80
	1000	29.45	106.02	65.88		2000	39.52	142.27	88.40
	1200	27.21	97.96	60.87		3000	36.51	131.44	81.67
	1500	25.60	92.16	57.27		∞	32.53	117.11	72.77
	2000	24.34	87.62	54.44					
	3000	23.31	83.92	52.15	$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	1553.33	86.74	312.26	194.03
	∞	21.69	78.08	48.52		2000	58.90	212.04	131.75
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	970.8	54.22	195.19	121.29		3000	51.19	184.28	114.51
	1000	46.27	166.57	103.50		∞	43.37	156.13	97.01
	1200	37.72	135.79	84.38					
	1500	34.05	122.58	76.17					
	2000	31.57	113.65	70.62					
	3000	29.75	107.10	66.55					
	∞	27.11	97.60	60.65					

Latitude 55°.

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$	$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	67.9	4.06	14.62	9.08	$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	203.7	12.16	43.78	27.20
	100	2.59	9.32	5.79		300	7.77	27.97	17.38
	200	2.24	8.06	5.01		400	7.16	25.78	16.02
	300	2.16	7.78	4.83		500	6.88	24.77	15.39
	400	2.12	7.63	4.74		600	6.71	24.16	15.01
	500	2.10	7.56	4.70		700	6.61	23.80	14.79
	600	2.09	7.52	4.67		800	6.53	23.51	14.61
	700	2.08	7.49	4.65		900	6.48	23.33	14.50
	800	2.07	7.45	4.63		1000	6.43	23.15	14.38
	900	2.07	7.45	4.63		1200	6.37	22.93	14.25
	1000	2.06	7.42	4.61		1500	6.31	22.72	14.12
	1200	2.06	7.42	4.61		2000	6.25	22.50	13.98
	1500	2.05	7.38	4.59		3000	6.19	22.28	13.84
	2000	2.05	7.38	4.59		∞	6.08	21.89	13.60
	3000	2.04	7.34	4.56					
	∞	2.03	7.31	4.54	$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	271.6	16.22	58.39	36.28
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	135.8	8.12	29.23	18.16		300	12.41	44.68	27.76
	200	5.18	18.65	11.59		400	10.36	37.30	23.18
	300	4.66	16.78	10.43		500	9.68	34.85	21.65
	400	4.48	16.13	10.02		600	9.33	33.59	20.87
	500	4.40	15.84	9.84		700	9.10	32.76	20.36
	600	4.32	15.55	9.66		800	8.95	32.22	20.02
	700	4.27	15.37	9.55		900	8.84	31.82	19.77
	800	4.25	15.30	9.51		1000	8.75	31.50	19.57
	900	4.22	15.19	9.44		1200	8.63	31.07	19.31
	1000	4.20	15.12	9.40		1500	8.52	30.67	19.06
	1200	4.18	15.05	9.35		2000	8.41	30.28	18.82
	1500	4.15	14.94	9.28		3000	8.30	29.88	18.57
	2000	4.13	14.87	9.24		∞	8.11	29.20	18.14
	3000	4.10	14.76	9.17					
	∞	4.06	14.62	9.08					

Latitude 55° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	339.5	20.28	73.01	45.37
	400	14.60	52.56	32.66
	500	12.95	46.62	28.97
	600	12.23	44.00	27.34
	700	11.81	42.52	26.42
	800	11.53	41.51	25.79
	900	11.34	40.82	25.36
	1000	11.19	40.28	25.03
	1200	10.98	39.53	24.56
	1500	10.79	38.84	24.13
	2000	10.61	38.20	23.74
	3000	10.44	37.58	23.35
	∞	10.14	36.50	22.68
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	509.2	30.42	109.51	68.05
	600	21.90	78.84	48.99
	700	19.99	71.96	44.71
	800	18.98	68.33	42.46
	900	18.34	66.02	41.02
	1000	17.89	64.40	40.02
	1200	17.30	62.28	38.70
	1500	16.78	60.41	37.54
	2000	16.33	58.79	36.53
	3000	15.92	57.31	35.61
	∞	15.21	54.76	34.03
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	679.0	40.56	146.02	90.73
	700	34.57	124.45	77.33
	800	29.20	105.12	65.32
	900	27.12	97.63	60.66
	1000	25.89	93.20	57.91
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	1200	24.45	88.02	54.69
	1500	23.31	83.92	52.15
	2000	22.37	80.53	50.04
	3000	21.58	77.69	48.27
	∞	20.28	73.01	45.37
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	848.7	50.70	182.52	113.41
	900	40.94	147.38	91.58
	1000	36.50	131.40	81.65
	1200	32.90	118.44	73.60
	1500	30.56	110.02	68.36
	2000	28.83	103.79	64.49
	3000	27.45	98.82	61.40
	∞	25.35	91.26	56.71
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	1018.5	60.84	219.02	136.09
	1200	43.80	157.68	97.98
	1500	38.84	139.82	86.88
	2000	35.78	128.81	80.04
	3000	33.56	120.82	75.07
	∞	30.42	109.51	68.05
$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	1358.0	81.12	292.03	181.45
	1500	62.04	223.34	138.78
	2000	51.78	186.41	115.83
	3000	46.62	167.83	104.28
	∞	40.56	146.02	90.73

Latitude 60°.

$\frac{0.2\ mm.}{100\ km.} = \frac{0.1\ in.}{789\ mi.}$	60.75	3.82	13.75	8.55
	100	2.36	8.50	5.28
	200	2.09	7.52	4.67
	300	2.03	7.31	4.54
	400	2.00	7.20	4.47
	500	1.98	7.13	4.43
	600	1.97	7.09	4.41
	700	1.96	7.06	4.39
	800	1.96	7.06	4.39
	900	1.95	7.02	4.36
	1000	1.95	7.02	4.36
	1200	1.94	6.98	4.34
	1500	1.94	6.98	4.34
	2000	1.93	6.95	4.32
	3000	1.93	6.95	4.32
	∞	1.91	6.88	4.28
$\frac{0.4\ mm.}{100\ km.} = \frac{0.1\ in.}{395\ mi.}$	121.5	7.60	27.36	17.00
	200	4.72	16.99	10.56
	300	4.33	15.59	9.69
	400	4.18	15.05	9.35
	500	4.10	14.76	9.17
	600	4.05	14.58	9.06
	700	4.02	14.47	8.99
	800	3.99	14.36	8.92
	900	3.98	14.33	8.90
	1000	3.96	14.26	8.86
	1200	3.94	14.18	8.81
	1500	3.92	14.11	8.77
	2000	3.90	14.04	8.72
	3000	3.87	13.93	8.66
	∞	3.80	13.68	8.50

Latitude 60° (Continued).

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{0.6\ mm.}{100\ km.} = \frac{0.1\ in.}{263\ mi.}$	182.25	11.40	41.04	25.50
	200	8.87	31.93	19.84
	300	7.08	25.49	15.84
	400	6.62	23.83	14.81
	500	6.40	23.04	14.32
	600	6.27	22.57	14.02
	700	6.19	22.28	13.84
	800	6.13	22.07	13.71
	900	6.08	21.89	13.60
	1000	6.05	21.78	13.53
	1200	5.99	21.56	13.40
	1500	5.94	21.38	13.29
	2000	5.89	21.20	13.17
	3000	5.84	21.02	13.06
	∞	5.70	20.52	12.85
$\frac{0.8\ mm.}{100\ km.} = \frac{0.1\ in.}{197\ mi.}$	243.0	15.20	54.72	34.00
	300	10.69	38.48	23.91
	400	9.43	33.95	21.10
	500	8.94	32.18	20.00
	600	8.66	31.18	19.37
	700	8.49	30.56	18.99
	800	8.37	30.13	18.72
	900	8.28	29.81	18.52
	1000	8.21	29.56	18.37
	1200	8.11	29.20	18.14
	1500	8.01	28.84	17.92
	2000	7.92	28.51	17.72
	3000	7.84	28.22	17.54
	∞	7.60	27.36	17.00
$\frac{1.0\ mm.}{100\ km.} = \frac{0.1\ in.}{158\ mi.}$	303.75	19.00	68.40	42.50
	400	12.87	46.33	28.79
	500	11.79	42.44	26.37
	600	11.27	40.57	25.21
	700	10.95	39.42	24.49
	800	10.73	38.63	24.00
	900	10.58	38.09	23.67
	1000	10.46	37.66	23.40
	1200	10.29	37.04	23.02
	1500	10.13	36.47	22.66
	2000	9.99	35.96	22.34
	3000	9.85	35.46	22.03
	∞	9.50	34.20	21.25

$\frac{\Delta B\ (mm.)}{100\ km.}$	r	$V\frac{m}{s}$	$V\frac{km}{hr}$	$V\frac{mi}{hr}$
$\frac{1.5\ mm.}{100\ km.} = \frac{0.1\ in.}{105\ mi.}$	455.6	28.50	102.60	63.75
	500	22.17	79.81	49.59
	600	19.30	69.48	43.17
	700	18.09	65.12	40.46
	800	17.37	62.53	38.85
	900	16.90	60.84	37.80
	1000	16.56	59.62	37.05
	1200	16.10	57.96	36.02
	1500	15.69	56.48	35.09
	2000	15.31	55.12	34.25
	3000	14.98	53.93	33.51
	∞	14.25	51.30	31.88
$\frac{2.0\ mm.}{100\ km.} = \frac{0.1\ in.}{79\ mi.}$	607.5	37.98	136.73	84.96
	700	28.14	101.30	62.94
	800	25.74	92.66	57.58
	900	24.44	87.98	54.67
	1000	23.59	84.92	52.77
	1200	22.53	81.11	50.40
	1500	21.66	77.98	48.45
	2000	20.92	75.31	46.80
	3000	20.26	72.94	45.32
	∞	18.99	68.36	42.48
$\frac{2.5\ mm.}{100\ km.} = \frac{0.1\ in.}{63\ mi.}$	759.4	47.48	170.93	106.21
	800	39.14	140.90	87.55
	900	34.37	123.73	76.88
	1000	32.18	115.85	71.99
	1200	29.86	107.50	66.80
	1500	28.17	101.41	63.01
	2000	26.83	96.59	60.02
	3000	25.72	92.59	57.53
	∞	23.74	85.46	53.10
$\frac{3.0\ mm.}{100\ km.} = \frac{0.1\ in.}{53\ mi.}$	911.25	56.98	205.13	127.46
	1000	44.34	159.62	99.18
	1200	38.61	139.00	86.37
	1500	35.38	127.37	79.14
	2000	33.12	119.23	74.09
	3000	31.37	112.93	70.17
	∞	28.49	102.56	63.73
$\frac{4.0\ mm.}{100\ km.} = \frac{0.1\ in.}{39\ mi.}$	1215.0	75.96	273.46	169.92
	1500	53.44	192.38	119.54
	2000	47.18	169.85	105.54
	3000	43.32	155.95	96.90
	∞	37.98	136.73	84.96

Certain Hydro-electric Power Possibilities in the Provinces of Quebec and Ontario, Canada. L. SIMPSON. (*Proceedings of the American Electrochemical Society,* April 28–May 5, 1918.)—Only of late years has it been recognized that more is required of a hydro-electric power development than the existence of a large minimum supply of water under conditions that will permit its use under a reasonably high head, a fairly low cost of development, and a convenient location. It is now recognized that engineering conditions should be such that troubles from ice shall seldom occur and shall at all times be small. Troubles from ice during the last few years became a factor of an importance too considerable to be ignored. Hydro-electric powers which, when only partially developed, were comparatively free from troubles caused by ice, since their completion have been subjected to such serious ice troubles as to change the cost of an apparently low-priced power into one of high price when the loss caused by closing down was added.

In Canada and in the northern section of the United States there are now to be found but few undeveloped hydro-electric power propositions of magnitude that, when properly developed and at reasonable cost, will be comparatively free from ice troubles. Of such power propositions located in Canada and reasonably near the United States, that one situated upon the Ottawa River, 32 miles west of the city of Ottawa, known as the Chats Falls, is probably the best. It is possible at these falls to develop between 110,000 and 120,000 electrical horsepower. The possible head is 50 feet, and troubles from ice can be reduced to a minimum. Another proposition of great magnitude, and one that because of its magnitude may not be so quickly made available, is that which is possible through the construction of a canal from Lake St. Francis to a power-house located on the Lake St. Louis, both these lakes being enlargements of the River St. Lawrence. The possible head is 80 feet, and it will be possible to develop 1,000,000 horsepower.

One of the hydro-electric power developments using the water of Lake St. Francis is particularly interesting because the first direct-connected electric generator was installed in that plant. This generator was built by the General Electric Company, at its Schenectady, N. Y., works, upon an agreement with the then general manager of the Montreal Cotton Company, who proposed the plant, that the builders were to be relieved of all technical and financial responsibility. The success of the installation is now evidenced by the equipment of every modern hydro-electric power-house.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THERMAL EXPANSION OF ALPHA AND OF BETA BRASS BETWEEN 0-600°C[1].

By P. D. Merica and L. W. Schad.

[ABSTRACT.]

IN connection with the investigation of the failure of brass by cracking, a comparison has been made of the thermal expansions between ordinary temperature and 600° C. of the two constituents, alpha and beta, of which 60 : 40 brass is composed. The results show that whereas at ordinary temperature the unit expansions of beta brass (55 per cent. copper) and of alpha brass (65 per cent. copper) are very nearly equal — about 18×10^{-6} per degree C.—that of the beta brass becomes about 50 per cent. greater than that of the alpha between 400° and 450° C., just below the beta transformation temperature.

This difference in expansion must result in the existence of differential local or "grain" stresses in a heterogeneous brass containing both alpha and beta when quenched from temperatures higher than from 400 to 500° C. at such a rate of cooling that geometrical adjustment cannot take place between these elements of the mass. The stress distribution in such a quenched brass is very complex; an approximate calculation on certain very arbitrary assumptions would indicate the possibility of the development by quenching of average tensional stresses of 15,000 lbs. 1 sq. in. and more in the beta constituent.

The possible effect of such stresses on the mechanical properties and service behavior of brass and other material is discussed. Experiments showed that these stresses caused in all probability a decrease of the proportional limit over that in the quenched and annealed state. They have failed to show, however, that such quenched brass will "corrosion-crack" in the mercurous nitrate test.

Attention is called to the desirability of studying this feature of heterogeneous alloy structure more fully.

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* Communicated by the Director.

[1] Scientific Paper No. 321.

THE PHOTOELECTRIC SENSITIVITY OF BISMUTHINITE AND VARIOUS OTHER SUBSTANCES.[2]

By W. W. Coblentz.

[ABSTRACT.]

This paper summarizes the results of an investigation of various substances: (1) for an increase in electrical conductivity caused by the action of light upon them, and (2) for photoelectrical activity when they were charged to a negative potential, in an evacuated chamber, and exposed to light.

Pure gallium and silver sulphide were found to have but small photoelectric activity when charged to a negative potential and exposed to light.

No change was observed in the electrical conductivity of tellurium, boleite, pyrite, silicon, and mixtures of the sulphides of lead and antimony, when exposed to light.

An increase in conductivity was observed in crystals of bismuthinite, cylindrite, molybdenite, selenium, stibnite, boulangerite, jamesonite, and silver sulphide when exposed to light.

Experiments are described in which some of these substances were joined through a battery to the grid circuit of an audion amplifier and a telephone. The light stimulus was interrupted by means of a rotating sectored disk, as used in Bell's selenium photophone. When using a cell or crystal of selenium the fluctuations in light intensity produced a sufficient change in conductivity to cause a musical note in the telephone. Similarly, in some samples of bismuthinite and of molybdenite, a change in conductivity was produced, which caused an audible sound in the telephone receiver. Further experiments are in progress to determine to what extent and for what wave-lengths this is a true photoelectric change (increase) in conductivity, and to what extent this is caused by fluctuations in temperature with a resultant change in resistance within the crystal.

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[2] Scientific Paper No. 322.

WAVE LENGTHS IN THE RED AND INFRA-RED SPECTRA OF IRON, COBALT AND NICKEL ARCS.[3]

By W. F. Meggers and C. C. Kiess.

[abstract.]

It has long been known that the sensitiveness of photographic plates to yellow, red and infra-red light may be increased by staining the plates with certain dyes, but the use of such stained plates in spectrum photography has not been very common. The scarcity of accurate data for wave lengths greater than those of yellow light has led the Bureau of Standards to make extensive application of photographic sensitometry to the study of long wave-length regions in the spectra of the chemical elements. It was thought especially desirable to know to what extent photographic methods combined with powerful dispersive apparatus are applicable to the infra-red spectral regions.

The long-wave regions of the arc spectra of ferrous metals were recorded on plates stained with pinacyanol and with dicyanin. The photographs were made in the first order spectrum of a concave grating with 645 cm. radius of curvature. Exposures of ten minutes' duration sufficed to register the spectrum up to 7000 A; between 7000 A and 9000 A, twenty to thirty minutes' exposure was sufficient, while five to ten hours of exposure recorded many lines whose wave lengths exceed 10,000 A, or one micron. In the arc spectrum of iron, 298 lines were measured between the wave-length limits 6750 A and 10,689 A; 606 lines were measured between 5503 A and 11,623 A in the arc spectrum of cobalt, and 290 lines between 5504 A and 10,843 A in the arc spectrum of nickel. The large number of lines photographed in the infra-red spectra of these arcs shows the importance of using and developing photographic methods as far as possible. The photographic has great advantages over the radiometric method in being able to record fainter lines and resolve complex or close lines, in addition to allowing greater possible accuracy in the wave-length measurements. In the spectral region in which the above mentioned photographs overlap radiometric observations, from 5 to 10 times as many lines

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[3] Scientific Paper No. 324.

were recorded as were observed by means of the radiometer. However, for waves longer than about 10,000 A the sensitiveness of the radiometer so enormously exceeds that of photographic plates at the present time that it is necessary to rely on the radiometer for practically all spectroscopic data. Extensive and careful investigations in the region to which both methods apply should assist in removing some of the difficulties and uncertainties in studying the longer waves. For this purpose the use of dicyanin is strongly recommended since it makes an invisible long wave interval as large as the entire visible spectrum accessible to photography.

SPECTRO-RADIOMETRIC INVESTIGATION OF THE TRANSMISSION OF VARIOUS SUBSTANCES.[4]

By W. W. Coblentz, W. B. Emerson and M. B. Long.

[ABSTRACT.]

THIS paper gives the spectral transmission of various substances, especially colored fluorite and colored glasses.

In some scientific investigations it is desired to expose large areas to radiant energy stimuli of a fairly high spectral purity. Some of the substances described in this paper provide a simple means of obtaining narrow spectral bands of energy of high intensity, and large area without employing a spectroscope.

By properly combining these substances one can obtain a screen having a narrow band of high transmission at 0.38 μ, 0.5 μ, 0.55 μ, 0.7 μ, 0.8 μ, 1 μ, and 2.2 μ.

The data on glasses are also useful in connection with the question of protecting the eyes from injurious radiations.

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[4] Scientific Paper No. 325.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE IODIDE TITRATION OF SILVER NITRATE WITH PALLADIOUS NITRATE AS THE INDICATOR.[1]

By Louis Schneider.

[ABSTRACT.]

THIS new method is especially adapted for the determination of very small amounts of silver with accuracy, and overcomes the effect of those metals that usually interfere with the Volhard method. The method consists of the titration of silver nitrate with potassium iodide in the presence of a very small amount of palladious nitrate. The silver nitrate is precipitated by the potassium iodide and the slightest excess of potassium iodide is converted by the palladious nitrate to palladious iodide which is strongly colored.

In applying the palladium indicator it was found necessary to employ a protective colloid, such as gum arabic to prevent the occlusion of silver nitrate or potassium iodide in tenth normal titrations, and, in very dilute solutions, in order to obtain a precise colorimetric comparison in determining the end point.

The errors of the method are discussed and may be avoided by adherence to the recommended method of procedure. An accuracy of 0.1 per cent. is easily obtained.

A NEW METHOD OF OBTAINING DYE TONED IMAGES BY THE USE OF COPPER FERROCYANIDE AS A MORDANT.[2]

By J. I. Crabtree.

[ABSTRACT.]

As a result of a search for mordants of basic dyes other than silver iodide, it was found that by replacing more or less

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* Communicated by the Director.

[1] Communication No. 59 from the Research Laboratory of the Eastman Kodak Company, published in *Journal American Chemical Society,* April, 1918, p. 583.

[2] Communication No. 72 from the Research Laboratory of the Eastman Kodak Company, published in *Phot. J. Am.*, 1918, p. 338: *Mot. Pic. News*, Aug. 17, 1918, p. 1104, and Aug. 24, p. 1278.

of a silver image by copper ferrocyanide, by toning in the usual copper-toning bath, washing, and then immersing in an acid solution of a basic dye, dye-toned images were obtained.

The usual copper toning bath consists of a solution of copper ferricyanide dissolved in a suitable solvent, such as a solution of an alkaline salt, of citric, tartaric, or oxalic acid, together with other salts. On immersing the silver image in such a bath the silver reacts with the copper ferricyanide and is converted to silver ferrocyanide, while copper ferrocyanide is formed simultaneously in combination with the image.

On immersing this image in a solution of a suitable basic dye a composite image is obtained consisting of a mixture of silver, silver ferrocyanide, copper ferrocyanide and the dye, so that the color of the toned image produced is of a color intermediate between that of the dye and the copper compound, depending on the relative proportion of each. The amount of copper salt necessary to mordant the dye is usually so small that the resultant tone differs but slightly from that of the dye itself. After toning in the copper-toning bath for a few minutes the positive is washed for ten minutes and immersed in the dye solution, which contains a little acid. After dyeing only a mere rinse of water is necessary before drying.

If the highlights are stained, the positive should be washed for five or ten minutes or until clear. Stained highlights are caused either by insufficient washing after toning, too strong a dye bath, or an incorrect amount of acid in the dye bath.

Satisfactory tones may be secured with the following dyes: Tannin Heliotrope, Thioflavine, Victoria Green, Methyl Green, Methylene Blue, Chrysoidine, Methyl Violet.

Intermediate dye tones may be obtained by mixing two or more dyes, and pale tones by giving a short bath in the copper solution and fully dyeing, or by toning for a longer time and giving a short immersion in the dye bath.

A feature of the toned images produced in the above manner is their transparency. The transparency depends on the composition of the copper toning bath and on the fineness of grain of the silver image to be toned. For toning lantern slides the best results are obtained on the "slow" variety of plates, which are usually of fine grain.

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Yorke, George M., Major	Signal Corps, U.S.R.	New York

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Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia

Name	Appointment	Location
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York

Name	Appointment	Location
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N J
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 4, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 4, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2722.—Calorizing Process.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, September 11, 1918.)

RESIDENT.

MR. ALFRED CROOK, Vice President and General Manager, Philadelphia Roll and Machine Company, 25th Street and Washington Avenue, Philadelphia, Pennsylvania.

Mr. Charles S. Hollander, Chemist and Chemical Engineer, Rohm and Haas Company, Bristol, Pennsylvania.

NON-RESIDENT.

Mr. William E. Bullock, Mechanical Engineer, 26 Maxweber Avenue, Jamaica, New York.

Mr. Francis G. Pease, Astronomer and Engineer, Solar Observatory, Pasadena, California, and for mail, 1023 16th Street, Washington, D. C.

Mr. James R. Watkins, Civil Engineer, Forest Products Laboratory, and for mail, 1315 Spring Street, Madison, Wisconsin.

ASSOCIATE.

Mr. William Hoppin, Internal Combustion Engineer, Y.M.C.A., Detroit, Michigan.

NECROLOGY.

Mr. G. W. Dickie, 24 California Street, San Francisco, California.

Mr. Joseph Hartshorne, 524 High Street, Pottstown, Pennsylvania.

BOOK NOTICES.

Journal of the American Ceramic Society. This is the initial number of a journal, to appear monthly, devoted to the "Arts and Sciences Related to the Silicate Industries." It is of usual octavo size, the present issue containing 72 pages of text with numerous illustrations and 10 pages of advertisements. One of the most interesting papers is by A. V. Bleininger, of Pittsburgh, on the manufacture of optical glass. From this we learn that a very important feature of the work is the production of suitable pots and this problem seems to have been practically solved. One of the speakers in discussion said: "We now have an optical-glass industry in this country well started, and we are able to take care of our military requirements with a very considerable degree of satisfaction."

The new journal will be welcome in the field of American scientific literature.

Henry Leffmann.

Agricultural Bacteriology. By H. W. Conn, Ph.D. Third edition, revised by Harold Joel Conn. Philadelphia, P. Blakiston's Son & Company, 1918. x + 357 pages, illustrations, 12mo. Price $2.00 net.

Eight years have elapsed since the last revision of this treatise. In the present edition, special attention has been paid to those divisions of agricultural bacteriology in which the greatest advance has been made during that period.

The introductory chapters describe the general nature of microörganisms and their activities. The section on soil and water is devoted to such subjects as the carbon and nitrogen cycles, manure, sewage and its treatment, relation of bacteria to the ash constituents of plants, soil fertility, drinking water, and stream pollution. Among the subjects discussed in the section on milk are bacterial changes in milk, milk-born diseases, control of milk supply, and the manufacture of butter, oleomargarine, and hard and soft cheeses. The bacteriology of alcohol, vinegar, sauer-kraut, tobacco, silage, and flax are described in one chapter, while the preservation of food products by drying, cold, preservatives, and canning receives attention in another chapter.

The concluding chapters give an outline of infection, immunity, and resistance, and a description of diseases of plants and animals produced by bacteria, fungi, and other lower parasites.

The appendix of 20 pages is an elementary laboratory manual, describing laboratory apparatus and reagents and the preparation of media, and giving directions for experiments, such as isolation of bacteria in pure culture, determination of bacterial count, study of morphology, motility and biochemical activity, and disinfection.

JOSEPH S. HEPBURN.

PUBLICATIONS RECEIVED.

TNT Trinitrotoluenes and Mono—and Dinitrotoluenes. Their Manufacture and Properties, by G. Carlton Smith, B.S., 133 pages, 12mo. New York, D. Van Nostrand Co., 1918. Price, $2.00.

Methods of Measuring Temperature, by Ezer Griffiths, D.Sc., with an introduction by Principal E. H. Griffiths, F.R.S. 176 pages, illustrations, 8vo. London, Charles Griffin & Sons, Ltd., 1918. American representatives, J. B. Lippincott Company.

Chemical Combination Among Metals, by Dr. Michele Giua and Dr. Clara Giua—Lollini. Awarded the prize of the Cagnola foundation by the Royal Lombardy Institute of Science and Literature. Translated by Gilbert Wooding Robinson. 341 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Co., 1918. Price, $4.50 net.

The New Science of the Fundamental Physics, by W. W. Strong, B.S., Ph.D. 107 pages, 8vo. Mechanicsburg, Pa., S. I. E. M. Co., 1918. Price, $1.25.

Canada, Department of Mines, Mines Branch: Report on the building and ornamental stones of Canada. Vol. V. Province of British Columbia, by Wm. A. Parks, B.A., Ph.D. 236 pages, plates, maps, 8vo. *Report on the Clay Resources of Southern Saskatchewan,* by N. B. Davis, M.A., B.Sc. 93 pages, plates, maps, 8vo. *Mineral Springs of Canada. Part II. The Chemical Character of Some Canadian Mineral Springs,* by R. T. Elworthy, B.Sc. 173 pages, plates, 8vo. *Annual Report on the Mineral Production of Canada during the Calendar Year, 1916,* John A. McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 343 pages, 8vo. Ottawa, Government Printing Bureau, 1918.

U. S. Bureau of Mines: Bulletin 145, Measuring the temperature of gases in boiler settings, by Henry Kreisinger and J. F. Barkley. 72 pages, illustrations, 8vo. Monthly statement of coal-mine fatalities in the United States, May 1918, compiled by Albert H. Fay. 25 pages, 8vo. Technical Paper 187, Slag viscosity tables for blast-furnace work, by Alexander L. Feild and P. H. Royster. 38 pages, 8vo. Technical paper 190, Methane accumulations from interrupted ventilation with special reference to coal mines in Illinois and Indiana, by Howard I. Smith and Robert J. Hamon. 46 pages, plates, 8vo. Washington, Government Printing Office, 1918.

United States Tariff Commission: Tariff Information Series No. 5. The glass industry as affected by the war. 147 pages, 8vo. Washington, Government Printing Office, 1918.

The Deposition of Silver Films on Glass. A. SILVERMAN and R. M. HOWE. (*The Journal of Industrial and Engineering Chemistry*, vol. 9, No. 11, p. 1032, November, 1917.)—The purpose of this investigation is threefold: to produce the best mirrors possible, to secure the highest possible percentage deposition, and, if possible, to obtain these results at room temperatures.

In hot processes cane-sugar is the most satisfactory reducing agent. Other sugars give good results, but no better than cane-sugar. The tartrates are not as satisfactory as the sugars. A rapid cold process was developed. It requires a batch of the following proportions used as indicated: 20 c.c. of 0.2 molar silver nitrate solution are mixed with 0.5 c.c. of 80 per cent. methyl alcohol; to this 0.5 c.c. of 40 per cent. formaldehyde is added and the whole mixed thoroughly.

A slow cold process was developed which is based upon the following principles: (1) Low concentration of the reducing agent (formaldehyde) gives the best results. This helps lengthen the time of reaction. (2) Low concentration of silver nitrate gives high deposition percentages. (3) Sugar added to the solution in sufficient amounts controls the action of the formaldehyde in such a way as to produce even mirrors. It also lengthens the time of action. (4) Alcohol added to the solution results in a high deposition efficiency. By grouping these principles the following batch results: 16.5 c.c. of 0.037 molar silver solution; 1.0 c.c. of 1.000 molar cane-sugar solution; 0.5 c.c. of 80 per cent. methyl alcohol; 2.0 c.c. of 0.8 per cent. formaldehyde solution. Total, 20 c.c. After 40 minutes, over 20 per cent. of the total silver deposits as mirror in each case, and if left longer a heavier mirror results. The cost of materials is not over one cent per square foot, and eleven cents per square metre of surface silvered. The mirror is very firmly attached to the glass for two reasons: (1) The temperature of the glass and solution is the same: as a result, deposition is more uniform than that which occurs at higher, more difficultly controllable temperatures. (2) Since deposition takes place at room temperature, differences in coefficient of expansion do not cause the newly formed mirror to be loosened from the glass, as may be the case where hot processes are employed.

CURRENT TOPICS.

American Artillery. Anon. (Circular from the Committee on Public Information, April 20, 1918.)—To-day the two dominating factors in the struggle for world supremacy are still the bayonet and heavy artillery. Without the support of either success is impossible. Big guns play a major part in deciding battles, now as in the day of Napoleon. For this reason it is interesting to know something about the different kinds of big gun being made for our army in France. Artillery may be divided into two classes—mobile artillery, which includes all guns used in the field, and seacoast artillery, which is used in fortifications on fixed mounts. It is the mobile artillery which we are vitally interested in at the present time for offensive work on the French front. This mobile artillery is divided into three distinct types—guns, howitzers, and mortars.

The first of these are long-range rifles distinguished by high muzzle velocity and long barrels of from 30 to 50 calibres; that is to say, the length of barrel ranges from thirty to fifty times the diameter of the bore, giving a range of from 6000 to 30,000 yards with a low angle of fire. These guns are classified as wheel mounts, anti-aircraft (truck mounts), emplacement mounts, and railway mounts. The wheel mounts are subdivided as pack artillery (mountain guns transported on pack mules); field guns, drawn by horse teams and attached to rumbles; motorized field guns, drawn by big ammunition trucks; tractor-drawn guns of large calibre; and the so-called horse artillery, drawn by horses, with all cannoneers mounted, for fast field work in support of cavalry.

The wheel-mount guns include the famous French 75 (3-inch) and 4.7-inch guns, which have created such havoc among their German opponents and which have been responsible for breaking down the greatest military offensives of the Germans in the past three years. The 4.7 are of greater range and calibre, but of practically the same type as the 75 mm. Next in order, according to size, come the 5-inch and the 6-inch seacoast guns, such as our allies have withdrawn from the fortifications and mounted on improvised wheel mounts, for use as mobile artillery.

The second class are the anti-aircraft guns, for which purpose 75's and 4.7's are provided, mounted on a carriage which will allow an elevation of about 85 degrees and a traverse of 360 degrees, set up on a motor truck. Emplacement mounts are large-calibre guns that are partially mobile. They are taken apart and moved around in sections in tractors as needed, and set up in concrete emplacements. They are, more strictly speaking, siege guns. The railway-mount guns are converted seacoast and naval long-range rifles of from 8 to 14 inches calibre. They have a mount consisting of a specially designed carriage on a railway car and they are operated, due to their extreme range and accuracy, far back from the front lines over the heads of our own troops. This covers the first class of mobile artillery—the long-range rifles. Next in order come the howitzers.

The howitzer is distinguished from the rifle by a low muzzle velocity ranging from 1200 to 1900 feet per second, and a short barrel, approximately eighteen times the calibre of the gun, developing a range at high angle fire of from 10,000 to 23,000 yards. The commonest sizes of howitzer in use are the 155-mm., the 8-inch, the 240-mm., and, of course, the famous 16-inch howitzer which we heard so much about in the early days of the war, when the Germans, who first used them, created such dreadful havoc, destroying with them the fortifications of Liège. The smaller sizes, such as the 155-mm. and the 8-inch, are used principally for field work, but also for the bombardment of permanent fortifications when necessary.

Howitzers have the advantage of being cheaper to make than guns, and use cheaper ammunition. Also, the life of the gun is longer. Indicative of this, the life of a howitzer of the same calibre as a gun would be about two-thirds longer. But they are not as accurate and have not as long range as the guns and consequently are not adapted for all work. The life of the guns ranges from 8000 rounds for the small field type down to 600 or 700 for the converted seacoast guns. These figures denote only the actual accuracy life. It is probable that the guns will be fired up to 50 per cent. above these figures before retiring them. By relining the barrels the life of the gun is practically renewed.

Mortars are distinguished by even lower muzzle velocity, from about 480 to 2000 feet per second, and by a length of barrel of about 10 calibres, with a range of from 2500 to 15,000 yards. This extreme range is obtained by a very high angle of elevation. The common French type is the 240-mm. mounted on a railway carriage.

This practically covers the principal guns which are used by our allies to-day and with which our troops will be equipped in France. The 3-inch and 4.7-inch guns, U. S. Army Model of 1906, are practically the same in general principle as the French 75 and 155, which are of the corresponding calibre. But it must be remembered that our allies have had three years' actual experience with which to perfect many of the minute details which are so important in the effectiveness of a field gun and which are only discovered under actual field conditions of long duration. This has led to great improvements over the guns originally in use.

As indicative of the tremendous amount of material that one regiment of 75's comprises, it is interesting to know that there are approximately 300 vehicles, exclusive of the actual fighting material, to each regiment. These vehicles are trailers, tractors, and trucks, and artillery repair trucks and supply trucks. In the actual fighting material there are 24 guns, 36 caissons, 60 limbers, and the reel carts for the field telephone, making a grand total of approximately 430 vehicles to a regiment.

The estimated cost of the motorization of the artillery alone of the United States Army is $500,000,000, of which approximately $210,000,000 had been expended on the 1st of February. Ammunition trucks and vehicles are being completed faster than they can be shipped. Up to the present time the sum of $776,000,000 has been expended by the Procurement Division of the Ordnance Department in the purchase of projectiles. With this sum about 65,000,000 projectiles have been purchased. These include shrapnel, high-explosive type, and gas and anti-aircraft shells for howitzers and guns, weighing from 12 pounds to 1600 or 1700, and costing from about $10 to $125 each, exclusive of the cost of explosives or of loading the complete round.

The Electrolytic Behavior of Manganese in Sulphate Solutions. G. D. VAN ARSDALE and C. G. MAIER. (*Proceedings of the American Electrochemical Society*, April 28–May 5, 1918.)—In prewar times the manganese ore needed for the steel and other large-scale industries in this country was supplied by importation largely from Russia. Since the outbreak of the war importation from this source has ceased. There are large deposits of metallurgical manganese ore in Brazil, and fairly extensive, though largely undeveloped, deposits in this country. The two alternative solutions of the problem, therefore, have been either the diversion of sufficient shipping for importing manganese ore from Brazil or the development and utilization of our domestic deposits. Since shipping has been and is so urgently needed for other purposes, the second alternative would appear desirable, if possible. Moreover, since it is at least possible that the importation of high-grade ore will be seriously hindered for even a considerable period after the war, the use of domestic ore is not entirely one of immediate or temporary expediency.

While deposits of manganese oxide and carbonate ore are fairly extensive in the United States, many of them are of too low grade to be of much direct use. . Mechanical concentration of these ores has been unsatisfactory, particularly from the point of view of efficiency of recovery. Smelting of low-grade ores will always be attended with serious difficulties and large slag losses. It seems, consequently, that some chemical method of concentrating ores might be the best solution of the problem, and, if well established, might even persist under post-war conditions.

Some preliminary results of an attempt to solve the problem along electrochemical lines are given in this paper. It was early realized that the most practical and convenient avenue for separating manganese from its ores was solution as manganese sulphate. Such a solution is also the form most amenable to electrolytic treatment. Current efficiencies, voltages, and conditions affecting the nature of the deposits formed by electrolyzing manganese sulphate have been studied. The factors affecting the deposition of elementary manganese at the cathode are discussed. The efficient plating-out of manganese dioxide at the anode is shown to be possible under certain circumstances, and the chemical conditions influencing the possible utilization of this reaction are pointed out.

Cast Iron at High Temperatures. ANON. (*Power,* vol. 48, No. 4, p. 120, July 23, 1918.)—Comparatively little information is available on the strength of iron and steel at high temperatures. Most of the tests published are of European origin and are either buried in voluminous reports or in foreign-language literature. These tests have recently been sought and collected by the Vulcan Soot Cleaner Company. Permanently installed soot cleaners must often be placed in temperatures that are comparatively high, and it is important to have data on the strength of the materials employed under these conditions.

As the temperature is increased, steel, wrought iron and cast iron grow stronger up to a certain point. Thus the maximum strength of wrought iron occurs at 450° Fahr. and the corresponding temperature for steel is 525° Fahr. With further increase in temperature both the ultimate and elastic strength decrease rapidly. At 1000° Fahr. the strength of wrought iron is seriously diminished, and steel has no elastic strength. If soot-cleaner elements are made of steel alone, and if they are heated to a temperature of 1000° Fahr. they are liable to sag from their own weight and become inoperative in a short time. The diminution of the strength of cast iron, on the other hand, is much less within the same temperature-range, the strength of soft cast iron is practically constant between 100 and 1000° Fahr. Cast iron of almost any good composition will protect soot-cleaner elements sufficiently, but for the sake of safety a special tested uniform grade is used. Besides being little affected by the temperature, the cast iron sheath, making the element somewhat larger, increases the rate of radiation and thus insures a lower temperature.

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THE MEASUREMENT OF TRANSMISSION-FACTOR.

BY

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INTRODUCTION.

In a previous paper one of the authors[1] pointed out the difficulties in the measurement of reflection-factor and showed that, notwithstanding the nonchalance with which values of reflection-factors are usually presented, such measurements are generally difficult to make and even more difficult to express with meaning. Except in the ideal cases of perfectly specular and diffuse reflection, the reflecting characteristics of media cannot be expressed simply by means of mathematical relations. Furthermore, the determination of the reflection-factor cannot be attained by measuring a single quantity, except in the two ideal cases already noted, unless the method involves integration. There are many factors, such as surface character of the medium, the distribution of brightness in the light-source and the character of the illumination, which so influence the reflection-factor that the latter cannot be taken as an invariable value for a given medium, except for the conditions under which it is determined. In the former paper the question of color, which includes such factors as the spectral character of the illuminant, the spectral transmission of the medium, and the

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* Communicated by Mr. Luckiesh.

[1] Measurement of Reflection-Factor, M. Luckiesh, *Elec. Wld.*, May 19, 1917.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

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method of photometry, was discussed. It was also stated that a similar general analysis was being prosecuted with respect to transmitting media. For further details and conclusions regarding the measurement of reflection-factor the reader should consult the former paper.

Most of the discussion of the measurement of reflection-factor applied equally well, with obvious modifications, to the determination of transmission-factor. The aims of the present work were to show the influence of various factors and to obtain a simple, practical method of measuring transmission-factor by the determination of a single quantity. Of course, it is obvious that the transmission-factor may be computed by mathematical integration for a given set of conditions if the transmission-characteristic curve is known, but this method is a tedious one and, in many cases of slightly diffusing or coarsely refracting media, it is not satisfactory. In order to conserve space many of the details will be omitted because the previous treatment[1] of this should suffice.

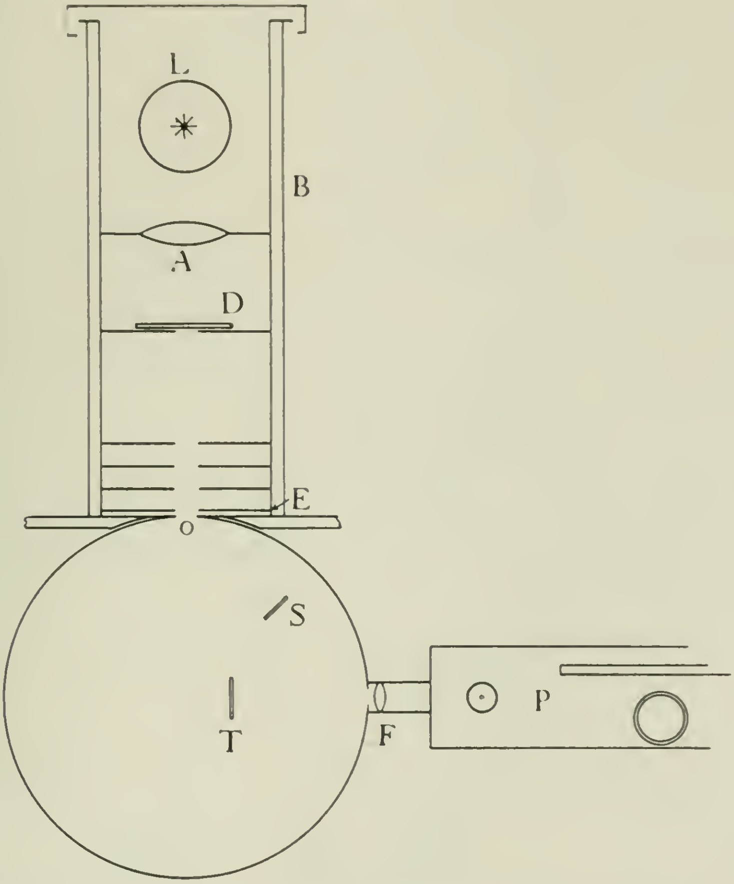
APPARATUS AND METHOD.

As already stated, one of the aims of this work was to devise a practical method and apparatus for determining transmission-factors which required the measurement of only a single quantity. For this reason an integrating method is necessary and, consequently, the sphere was chosen as a fundamental. A brass sphere, about 15 inches in diameter, was spun for this purpose. Inasmuch as the distribution of illumination is an important factor, it appeared best to choose types which could be readily described and reproduced. Two types were chosen, namely, a parallel beam of small cross-section, directed perpendicularly to the surface of the specimen under investigation, and diffused hemispherical illumination. These correspond, for example, to the direct light from the sun, and to the diffused light from an unobstructed, uniformly bright sky respectively. A Sharp-Millar photometer was used throughout the measurements, care being taken to operate within its best range.

Several variations in the apparatus were made in order to obtain comparative data which it was hoped would indicate a satisfactory method to be used eventually. These are shown in Figs. 1, 2, and 3.

In Fig. 1 the sphere is seen in relation to the photometer *P*, and the box *B* from which a directed beam of light was obtained. Over the opening, *O*, which was ⅞ inch in diameter, the specimens of transmitting media were placed. Just above the latter was a screen, *E*, covered with black velvet, and similar screens were placed above this one as indicated. The openings in these screens were about one inch in diameter. A sand-blasted glass was placed at *D*, a large lens at *A*, and a concentrated-filament tungsten lamp at *L*. The box was ventilated by means of light-traps and was painted black inside. The screens were covered with black velvet on both sides and the inner surface of the sphere was painted with a matt white paint as neutral in color as it could be conveniently made. The target, *T*, covered with the same kind of white paint, was placed perpendicular to the axis of the photometer and just outside the beam of light enter-

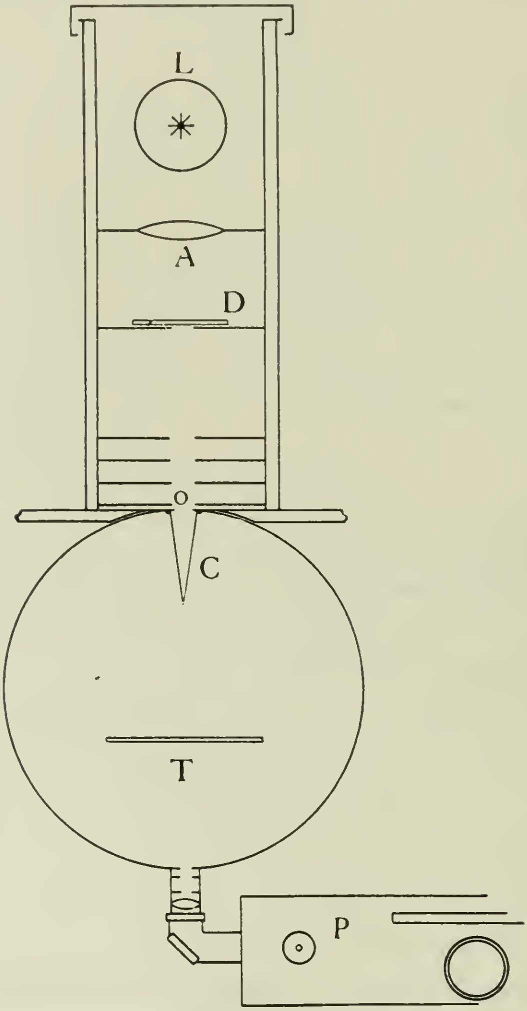
FIG. 1.



One arrangement of apparatus which yielded unsatisfactory results. See column 4 in the table.

ing *O*. A small screen, *S*, was placed as shown to shield the photometer opening in the sphere from any rays directed toward it from *O*. A lens, *F*, in the photometer tube brought the target in focus for the eye. The elbow tube of the photometer was not used in this case. The various precautions common to photometric work were observed. As might be expected, spurious determinations of transmission-factor were obtained owing to the very asymmetrical distribution of brightness in the sphere with respect to the photometer axis. The aim was to determine the brightness of the target, *T*, when a specimen of transmitting media was over *O*, in terms of the brightness of *T* when no

FIG. 2.



Apparatus used for determining transmission-factors of specimens illuminated by a narrow beam of light directed perpendicularly to the surface of each specimen. See column 5 in the table.

specimen was over the opening, O. The procedure and results are discussed later.

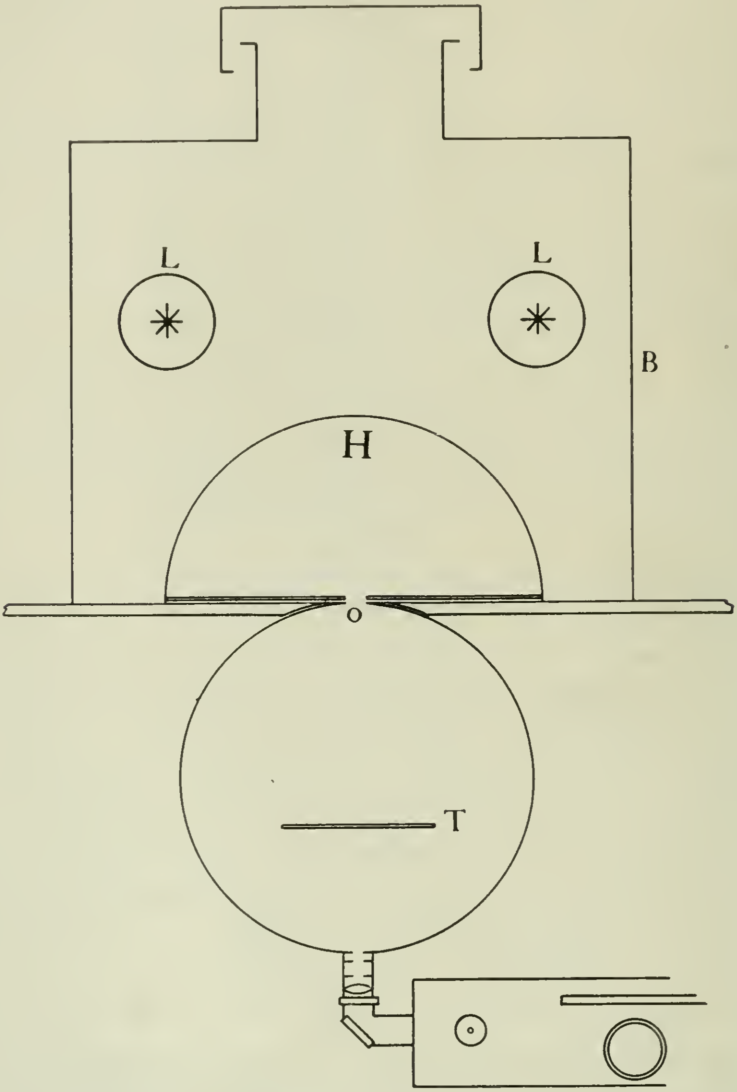
Next it appeared desirable to obtain symmetry in the arrangement of the various parts by placing the photometer at the bottom of the sphere as shown in Fig. 2. A large target was then placed as shown at T. This received light indirectly as before. In the case of slightly diffusing media, T intercepted the beam and scattered it to various parts of the surface of the sphere. Thus the light which reached the lower side of T arrived by very indirect routes. Only a small portion in the centre of T was viewed in making observations. Systematic measurements were also made with this arrangement which will be discussed later. For certain reasons it appeared worth while to attempt to scatter the light immediately upon entering O. Of the various forms which could be easily made, a long narrow cone appeared satisfactory. This hollow cone was made of clear glass with an open base 1.5 inches in diameter and about 4 inches long. Its exterior surface was then very finely etched and it was fastened as indicated in Fig. 2. Measurements with and without the cone, C, were made.

In Fig. 3 is shown the apparatus used for obtaining the transmission-factors for the same specimens illumined by diffused illumination. The sphere and photometer arrangement was the same as in Fig. 2, but the box supplying the parallel beam of light was replaced by the box, B, as shown. This was two feet square and was supplied with forced ventilation to keep the white inner surface from deteriorating owing to the excessive heating from the eight 200-watt tungsten lamps, L, used. A hemispherical bowl, H, of sand-blasted opal glass was placed symmetrically over the opening, O. This hemisphere was 16 inches in diameter. The aperture O was just even with the upper surface of the floor of the box B and was surrounded by black velvet. Upon this black velvet the specimen was placed and a thin velvet-covered screen 16 inches in diameter was placed over the specimen. The hole in this thin screen was one inch in diameter and was directly above O. Descriptions of minor mechanical details are omitted. By placing the eight lamps near the sides of the box and symmetrical with respect to the base of the hemisphere, by painting the inside of the box white, and by using a sand-blasted opal hemispherical bowl of moderate density it is reasonable to assume a fairly uniform illumination of *O* from all possible directions.

PROCEDURE.

First, without any medium over the opening, *O*, a set of ten observations was made. The glass to be studied was then introduced above *O* in contact with it and, with certain conditions of screening already noted, a set of ten observations was made. The specimen was removed and a set of observations was made similar to the first. Another set with the glass over *O* was made and finally another "clear" set. Therefore sets 1, 3, and 5 were

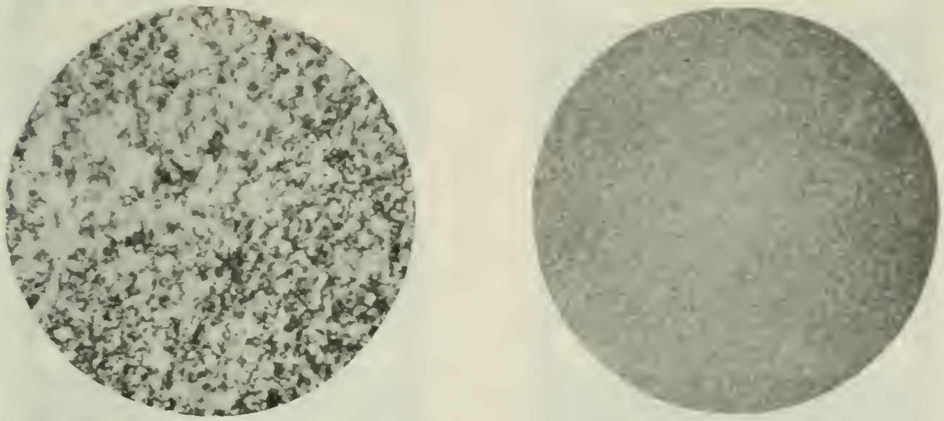
FIG. 3.



Apparatus used for determining transmission-factors of specimens for hemispherical illumination, that is, for thoroughly diffused light. See columns 6 and 7 in the table.

"clear" sets or, in other words, *O* was clear; sets 2 and 4 were made with the specimen of transmitting media over *O*. These five sets constituted a series and in the table all the individual values presented represent the mean from five or more series of five sets each, or each value represents 250 or more individual observations. The values obtained in each series were sufficiently consistent to inspire confidence in the results. The transmission-factor is computed from a single series by averaging the result of sets 2 and 4 and dividing this value by the mean of sets 1, 3, and 5. It is seen that the "clear" reading need be made only once, so that the transmission-factor thereafter would be obtained by determining the value of a single quantity. However, it is a safer plan to interweave these "clear" observations as indicated in the foregoing.

FIG. 4.



5 7

Photomicrographs of a coarse sand-blasted surface of clear glass (5) and of an acid-etched surface of clear glass (7). Equal magnification.

SPECIMENS OF GLASS.

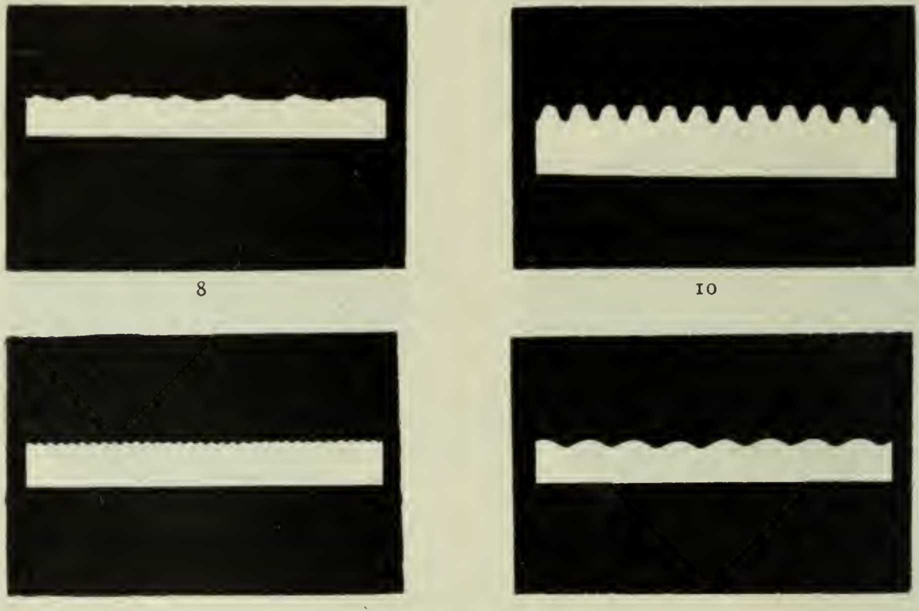
No. 5.—A thin sheet of clear glass, about 1/16 inch thick, sand-blasted on one side. A photomicrograph of its surface is shown in Fig. 4, contrasted with a photomicrograph of a very finely etched glass surface equally magnified. Various degrees of fineness may be obtained by means of the sand-blast. This specimen may be considered as fairly coarse.

No. 6.—A thin sheet of ordinary clear glass about 1/16 inch thick.

No. 7.—A thin sheet of clear glass, about 1/16 inch thick, etched on one side very finely and uniformly with acid. A photomicrograph of its surface is shown in Fig. 4, contrasted with one of No. 5.

No. 8.—A coarse pebbled glass, about 3/16 inch thick, with one side smooth. Photographs of its cross-section, of the coarseness of the pebbling, and of the character of the scattering of light from a very small light-source are shown in Figs. 5, 8, and 6 respectively. In Fig. 6 the scattering of light is shown for two cases, namely, when the rough and smooth sides faced the light-source respectively.

FIG. 5.



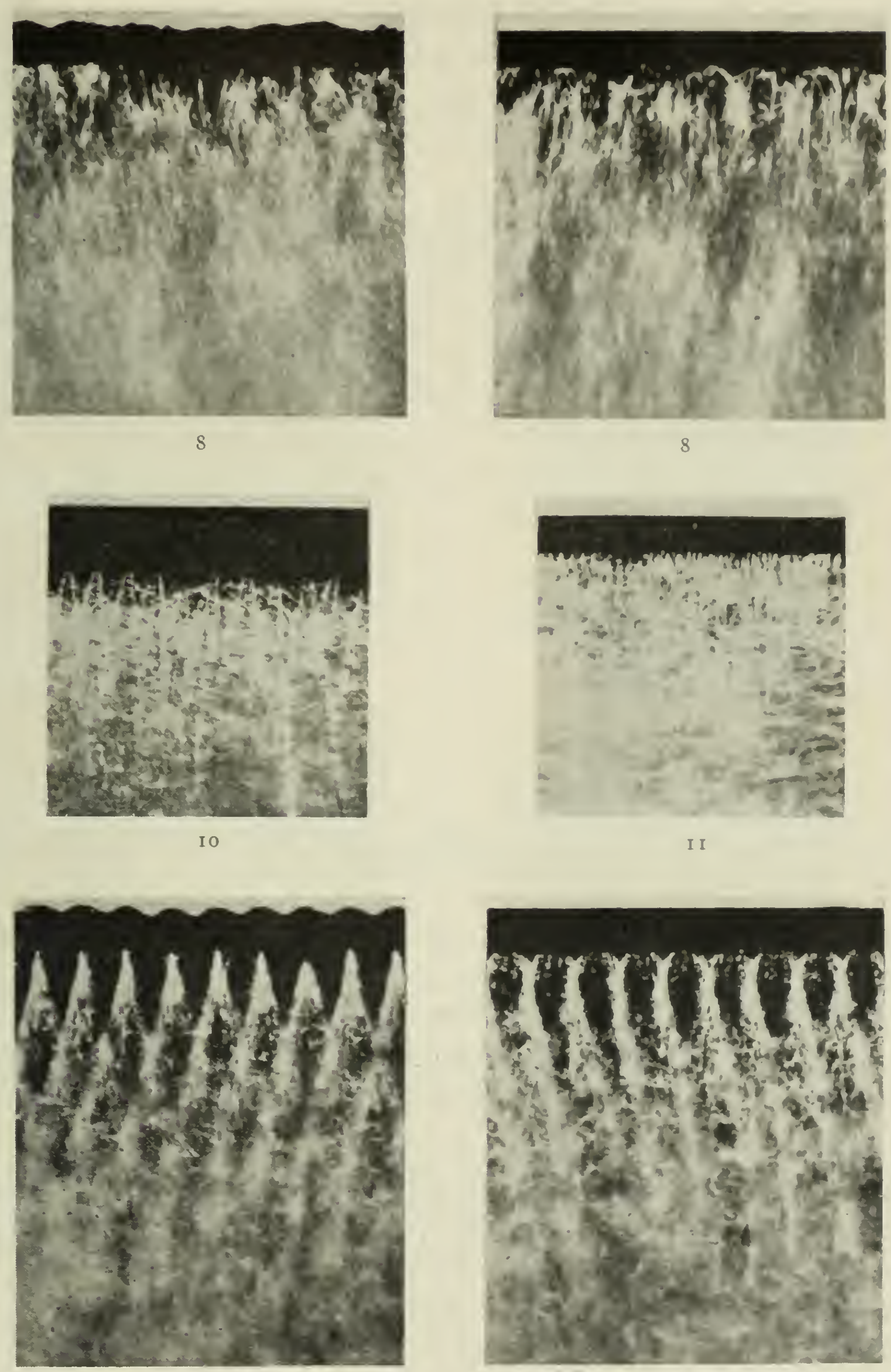
Full-size cross-sections of specimens of crystal glass, Nos. 8, 10, 11 and 12.

No. 10.—A clear glass about 5/16 inch thick, smooth on one side with about 8 ribs to the inch on the other side. The character of the ribs is shown in Fig 5. The character of the scattering of light from a small source of light is shown in Fig. 6 when the smooth side faced the light-source.

No. 11.—A clear glass, about 3/16 inch thick, smooth on one side with about 23 ribs to the inch on the other side. The character of the ribs is shown in Fig. 5, and the scattering of light from a small source of light is shown in Fig. 6 when the smooth side faced the light-source.

No. 12.—A clear glass, about 3/16 inch thick, smooth on one side with coarse, shallow, wavy ribs, about five to the inch,

Fig. 6.



8 8

10 11

12 12

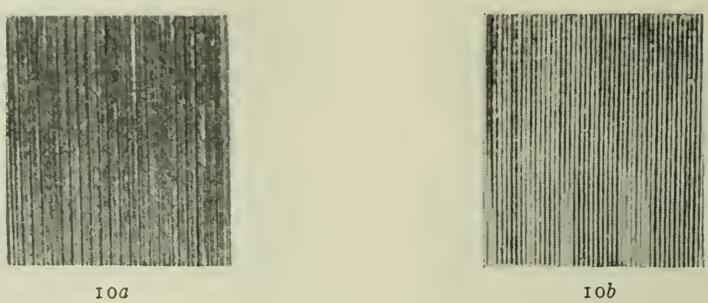
Showing the scattering of light by specimens 8, 10, 11 and 12. For specimens 8 and 12 two cases are shown, namely that for the rough surface toward the light source (left-hand illustrations) and that for the smooth surface toward the source (right-hand).

on the other side. The character of the ribs and of the scattering of light from a small source of light are shown in Figs. 5 and 6 respectively. In the latter the two cases are shown.

The cross-section photographs in Fig. 5 were made by placing a smooth blackened edge in contact with a photographic emulsion and exposing the plate by means of a slight-source in a proper position.

With certain glasses an idea of surface character may be obtained by printing a photograph by direct contact (Fig. 8), using a very small source of light. If successive exposures are made as the glass and plate are separated more and more, an idea of the distribution of light in the space near the glass is obtained. If the source subtends a large solid angle at the glass the surface character is not shown very well by contact printing and as a limiting case if the source is similar to an unobstructed overcast sky the surface character is almost, if not, entirely, obliterated. In the contact prints shown in Fig. 8 the rough side was in contact with the photographic plate in each case.

FIG. 7.



10*a* 10*b*

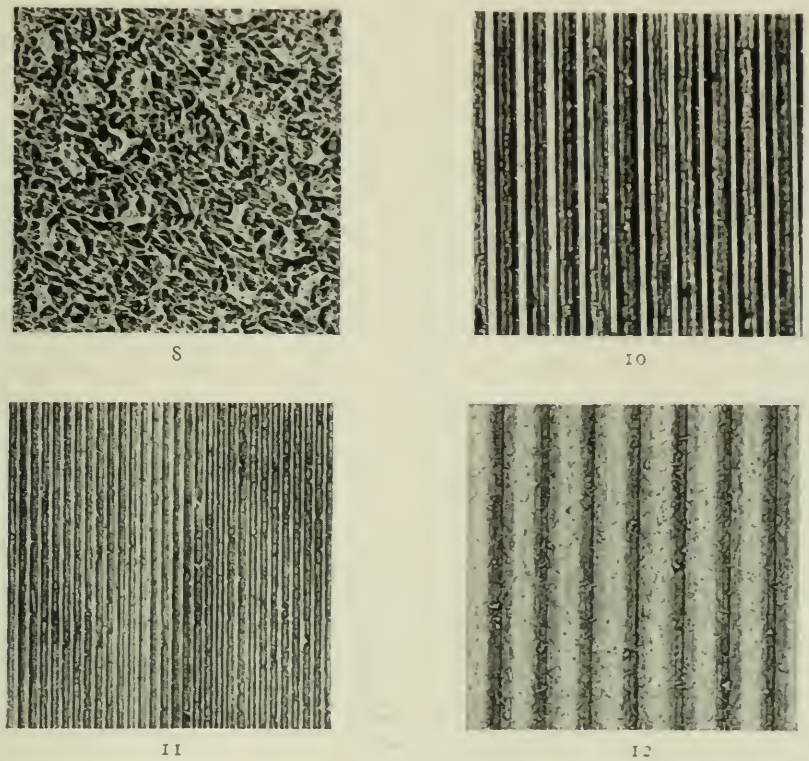
Showing different reflection-factors for specimen 10 depending upon the surface which faces the light-source. In *a* the ribs face the light-source; in *b* it has been reversed. This indicates also a difference in the transmission-factors. See table.

By placing the specimen of glass vertical with one edge in contact with a horizontal photographic plate and permitting light to pass through the specimen from a small source situated at some distance and just above the plane of the plate, a fairly accurate picture is obtained of the character of the scattering of light by the glass. By this means the scattered light just grazes the photographic plate and the many devious paths leave their records on the plate. Some photographs obtained in this manner are shown in Fig. 6.

These and many other effects may be recorded with ease without the use of a camera and the data revealed are interesting and show most of the characteristics of the glass quite well. If permanent records are not desired the same effects may be made visible to the eye by using diffusely reflecting and transmitting white media instead of photographic plates.

Of course, the appearance of a glass, which scatters light in a manner similar to these specimens, that is, not perfectly diffused, is of importance. This appearance for different conditions of illumination can best be recorded by visual observation or by photographing it with a camera.

FIG. 8.



The prints were made from negatives obtained by placing the rough side of the specimens in contact with a photographic plate. They were illuminated by means of a small light-source.

In attempting to record certain characteristics of these glasses a small source of light has been used because the other extreme kind of source (hemispherical illumination) blots out most of the effects. Some experiments and photographs of these characteristics were made with sources subtending solid angles varying from hemispherical to zero. These results are interesting and useful, but not essential to this paper.

Transmission-Factors Obtained Under Various Conditions.

(See Note.)

Specimen.	Relation of ribs to photometer axis.	Side toward light source.	Results by various arrangements of apparatus.				Ratio (with cone) diffuse / direct
			Small perpendicular beam.		Hemispherical illumination.		
			Fig. 1 without cone.	Fig. 2 with cone.	Fig. 3 without cone.	Fig. 3 with cone.	
			(Column 4)	*(Column 5)*	*(Column 6)*	*(Column 7)*	*(Column 8)*
			per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
6			91.3	91.2	90.0	90.0	98.9
5		Sand-blasted	91.7	78.3	71.1	70.2	89.7
5		Smooth	87.4	73.9	70.9	69.5	94.0
7		Etched	89.8	79.4	70.5	70.9	89.3
7		Smooth	84.6	75.8	70.7	70.4	92.9
8		Pebbled	89.9	84.6	74.7	74.6	88.2
8		Smooth	84.0	79.0	74.9	74.6	94.4
10	Perpendicular	Ribs (coarse)	119.7	76.6	61.5	61.7	80.5
10	Perpendicular	Smooth	69.5	51.5	61.8	61.6	119.6
10	Parallel	Ribs (coarse)	86.0	77.0	61.1	61.4	79.8
10	Parallel	Smooth	59.0	51.4	61.9	61.6	119.7
11	Perpendicular	Ribs (fine)	94.9	85.8	76.0	79.3	92.4
11	Perpendicular	Smooth	91.3	79.0	76.0	79.1	100.1
11	Parallel	Ribs (fine)	88.5	85.8	76.2	79.1	92.2
11	Parallel	Smooth	84.7	78.8	75.9	79.0	100.3
12	Perpendicular	Ribs (wavy)	94.4	88.4	79.6	82.2	92.9
12	Perpendicular	Smooth	96.7	86.0	79.9	82.1	95.5
12	Parallel	Ribs (wavy)	90.2	89.2	80.1	82.1	92.0
12	Parallel	Smooth	89.7	86.2	80.2	82.2	95.4

NOTE.—The values in column 4 (obtained with apparatus represented in Fig. 1) are of interest only in pointing out certain errors of the particular apparatus used in obtaining them. The values in columns 5 and 7 are considered to be satisfactory for the two types of illumination respectively. In the last column are to be found the ratios of the transmission-factor for perfectly diffused light (column 7) to that for a narrow pencil of light striking the specimen perpendicularly (column 5). Under the conditions of the experiments there is an uncertainty in the last figure given in the foregoing values.

RESULTS.

The results obtained with different arrangements of apparatus already described are presented in the table for certain representative specimens of glass which were elaborately studied. In this table the specimen number is given in the first column. In the second column the direction of the ribs is shown in relation to the axis of the Sharp-Millar photometer. In the third column is noted the position of the surfaces of the glass with respect to the source of light which illuminated it. In the next four columns transmission-factors are given in per cent., as determined under various conditions. The first column of values is of interest merely in showing the magnitude of the error which may arise from extremely asymmetrical conditions of illumination inside the sphere with respect to certain essential parts of the apparatus. The values in this column should be ignored beyond this; that is, they are not to be considered as absolute values.

In columns 5 and 7 the values are shown for the two types of illumination, directed and hemispherical respectively, when the diffusing cone was in place. The use of this cone under the opening *O* appears to be justified by the theory of it, by certain tests, and by some of the results. It will be noted that the result for clear glass illuminated by the narrow beam is about what it should be, namely 92 per cent., when the cone was used. Two different cones were used, one etched only on its exterior, the other on both its exterior and interior. These were removed and replaced, not necessarily in exactly the same position, without noticeably affecting the results. In order to ascertain more definitely the propriety of using such a device as the diffusing cone some tests were made. The opening *O* was reduced to one-half inch in diameter and a narrow beam of light was projected through it perpendicularly. Photometric readings were then made with both cones which were employed in the work. These cones were in various positions, such as symmetrical with *O*, at one side, tilted, etc., and in all cases the photometric readings agreed to within the accuracy of the apparatus. From these results and general experience the authors believe that the adoption of such a slightly diffusing device is not open to objection in a small sphere used for the present purpose. It will be noted that a narrow cone of this kind scattters the light very well without sending an appreciable amount back through the opening, *O*, thus overcoming the errors which may attend an extreme lack of uniformity of brightness inside the sphere. It is recognized that a certain error is possible for the case of hemispherical illumination, owing to the appreciable thickness of the glass as compared to the diameter of the opening, *O*, but this is ordinarily negligible. It is of interest further to consider the effect of the cone in connection with the results obtained for the ribbed glasses by comparing columns 6 and 7.

In the last column is found the ratio of the transmission-factor for diffused (hemispherical) illumination to that for a narrow beam of light, directed perpendicularly, as measured with the slightly diffusing cone in place. In other words, the last column represents the values in column 7 divided by those in column 5. It is seen, as was to be expected, that the transmission-factor is generally less for diffused light than for a narrow beam of light directed perpendicular to the surface of the specimen. It is easy to account for those values which are greater for diffused than for directed light, by the refraction and total reflection within the glasses, and by surface reflection.

The value of the transmission-factor for the clear glass, No. 6, is about what would be expected for the perpendicular beam of light. The loss of light in this case is almost entirely due to reflection at the two polished surfaces. This loss depends upon the refractive index of the glass and upon the angle of incidence of the light and was computed to be 92 per cent. The amount of light reflected by two polished surfaces of glass does not appreciably exceed 10 per cent. until the angle of incidence reaches the neighborhood of 60 degrees. When it is considered that, as the angle of incidence becomes greater than this angle, the subtended opening grows quite small, it is not surprising that the value of the transmission-factor for hemispherical illumination remains near 90 per cent. A rough computation yielded about 85 per cent. for this value. This difference may possibly be due to a lack of perfectly diffused illumination.

It is interesting to note that, for the case of a narrow perpendicular beam of light, the transmission-factor for the sand-blasted specimen, No. 5, is less when the smooth surface is toward the light. This was suspected by us from the viewpoint of total reflection inside the glass at the glass-air surfaces, but the authors are unaware of the fact having been noted before. When it is considered to act, in the favorable cases, similar to totally reflecting glass prisms, the difference in the values of the transmission-factor is easily accounted for. It should be noted that total reflection in glass prisms takes place at glass-air surfaces and not at air-glass surfaces. It is perhaps due chiefly to this that more light is reflected by a sand-blasted glass when the smooth surface is toward the light source than when the position of the surfaces is reversed. The difference in the transmission-factors for a beam of light passing the two ways through such a glass is the greater for the normal illumination; in fact, it should be obvious that such differences decrease as the illumination becomes more diffused or, in other words, as the light-source subtends greater solid-angles. In agreement with the preceding it is seen for No. 5 in column 5 that the transmission-factor when the sand-blasted surface is toward the light-source, is about 78 per cent. When the glass is reversed in position—that is, when the smooth side is toward the source, this value decreases to about 74 per cent. This difference, according to the measurements, is quite entirely eliminated for diffused illumination. It is of interest to note this difference in the case of the other samples. It becomes quite apparent to the eye for such a specimen as No. 10 as shown in column 5 and also photographically in Fig. 7. The specimen was photographed under conditions which exemplified the effect indicated by the determined values of transmission-factor. The light source was a window at a distance and the camera was placed between the window and the specimen. The exposure and development of the plate was the same for both cases. In *a* the ribs faced the camera and in *b* the smooth side was toward the camera. This point is emphasized strongly for the reason that it is of practical value.

In the cases of the ribbed glasses, the measurements were made with the ribs perpendicular to the axis of the Sharp-Millar photometer and also parallel to this axis. These values show the difficulties which may arise from an extreme lack of symmetry in the distribution of illumination in the sphere with respect to the target *T*, and they give an idea of the consistency of these determinations of transmission-factor (columns 5, 6, and 7).

The values in the last column show that the transmission-factor depends, among other things, upon the character of the illumination, being in general less for light emitted by a light source subtending a large solid angle at a point on the glass surface than for light directed normally to the glass from sources subtending small solid angles.

Attention is again called to the spurious values in column 4. These values are useful in the investigation, but if the reader is interested in transmission-factors he should refer to columns 5 and 7.

As previously stated the question of color has been eliminated entirely in this discussion, for the remarks in the previous paper apply equally well to the measurement of transmission-factor. In general it should be noted that the transmission-factor of a colored glass varies with the spectral character of the illuminant and that the different methods of photometry yield different results when the color-difference is appreciable.

SUMMARY.

An investigation has been made of various arrangements of apparatus designed for the determination of transmission-factor by the measurement of a single quantity. An integrating method has been studied, and under certain conditions appears to be satisfactory. The results appear satisfactory for practical purposes.

The transmission-factors have been obtained for several representative slightly diffusive glasses for two kinds of illumination; namely, (1) a narrow beam of light directed perpendicularly to the surface of the specimen, and (2) uniformly diffused light reaching the specimen from all directions above its plane. The latter may be known as hemispherical illumination. Some of these specimens may be described as coarsely refractive.

In general the transmission-factor is less for diffused (hemispherical) illumination than for a narrow beam of light directed perpendicularly.

It has been shown that the transmission-factor of such glasses as studied in this investigation depends upon the position of the glass with respect to the light-source for a narrow beam of light directed perpendicularly to the specimen. In other words, the transmission-factors are generally considerably greater when the rough surface faces the light-source than when the smooth side is toward it. This difference is very apparent visually in the case of ribbed glasses, but it has been found to exist even for so-called "frosted" or etched glasses.

Several simple photographic procedures have been carried out with the aim of representing certain characteristics of such glasses for which verbal description is unsatisfactory. These include the surface character, the cross-section, the appearance, and the scattering of light after passing through a specimen.

BIBLIOGRAPHY.

There is only a scanty literature on skylight glass, but various aspects of diffusing glass have been treated by others. The Transactions of the Illuminating Engineering Society contain many articles and discussions which should supply interesting material to those who may care to venture into the past literature on the general subject of transmitting media.

Dr. C. H. Sharp in his lecture in the I. E. S.—U. P. course in 1916 ("Illuminating Engineering Practice," p. 127)—briefly discussed the use of the integrating sphere for the measurement of the transmission factor of a diffusely transmitting medium.

Mr. E. J. Edwards (Trans. I. E. I., **9**, 1914, p. 1012), in a paper on "The Lighting of Rooms Through Translucent Glass Ceilings," presents the transmission factors of different types of glasses. He also discusses the important aspect of freedom from a spotted appearance when lighting units are installed above the skylight. In consideration of this point he presents the ratios of mounting height above the glass to the distance between units for the elimination of spotting for various types of glasses.

The Committee on Glare of the I. E. S., in one of its reports entitled "Diffusing Glassware" (Trans. I. E. S., **11**, 1916, p. 367), presented a discussion of certain diffusing characteristics. Dr. P. G. Nutting treated this aspect in a paper on "Reflection and Transmission of Light" (Trans. I. E. S., **7**, 1912, p. 616).

M. Luckiesh in two papers on "Diffusing Glassware" *(Electrical World,* **60**, 1912, p. 1040; **61**, 1913, 883) presented the transmission characteristics of a number of diffusely transmitting glasses.

A number of papers on illuminating glassware contain material of interest in connection with the problems treated in the present paper, of which the following are representative:

V. R. Lansingh: "Shades, Reflectors, and Diffusing Media," Vol. II, Lectures on Illuminating Engineering, Baltimore, 1910.

V. R. Lansingh: "Characteristics of Enclosing Glassware," Trans. I. E. S. Sept., 1913.

G. H. McCormack, A. J. Marshall, L. W. Young, and Bassett Jones: "Symposium of Illuminating Glassware," Trans. I. E. S. Sept. 1911.

W. F. Little: "Modern Lighting Accessories," 1916 Lecture Course of I. E. S. and U. P., "Illuminating Engineering Practice." p. 182. This paper contains a number of references.

NELA PARK, CLEVELAND, OHIO.
February, 1918.

Artillery and Small Arms for the United States Forces. H. O'HIGGINS. (*The Official Facts.* Committee on Public Information, Washington, D. C., September, 1918).—When we declared war, the military authorities of Great Britain and France offered to provide our expeditionary forces with big guns in order to save our ship tonnage from the burden of transporting heavy ordnance and to keep at a maximum production the ordnance works abroad. France and Great Britain had an adequate force of skilled workmen for making heavy ordnance and we had not. In this country all the factories that could make the large machine tools necessary for turning, boring and assembling big guns were already busy on contracts for the Allies. In order to prevent a confusion in Allied plans, to save ship tonnage, and to make a wise use of such arsenals and workmen as the Allies had, our War Department agreed to accept as much as possible of its first year's supply of guns abroad and to devote that year to developing its own big-gun industry.

The program has been carried out successfully. Our forces in Europe have had a sufficient supply of guns and ammunition purchased in Europe. Our men in the trenches have had the same heavy ordnance protection that the French and British troops have had. We have sent over some heavy artillery, to supplement the Allied supply, and we have developed our own designs, built our own factories, installed our machines and trained our own workmen for the manufacture of all sorts of big guns. We have spent five billion dollars on ordnance in our first year, and we are planning to spend twelve billion dollars in our second.

The complaint has been made that our ordnance bureau lost six months in vain efforts to improve on the perfect recoil mechanism of the famous French 75's. That is untrue. The charge is due apparently to the fact that we prepared designs for an American three-inch gun which was put into production before the models for the 75 arrived from France. We are making both guns, and our contracts call for the delivery of more than 3000 of them by January, 1919. After that date the 1917 model of the French 75 will be manufactured here at the rate of about 500 a month. Our own design of this gun, with the "split" carriage, is more flexible even than the French 75, and more deadly therefore to the enemy.

Of the six-inch sea-coast gun, our contracts provide for the delivery of 400 by January, 1919, and of 200 a month thereafter. Of the 155 millimeter howitzer, 1500 are to be delivered by January, 1919. Deliveries of the 240 millimeter howitzer are reaching 100 a month.

We are producing the light and heavy Brownings at the rate of about 5000 a week. We are turning out the new American rifle at the rate of 60,000 a week. Our automatic pistol, calibre 45, has already demonstrated its efficiency in close fighting. All these weapons are being produced in vast quantities, and our ordnance division has proved itself as resourceful as the men whom it has armed and as efficient as the weapons with which it has armed them.

SOIL ALDEHYDES.*

A SCIENTIFIC STUDY OF A NEW CLASS OF SOIL CONSTITUENTS UNFAVORABLE TO CROPS, THEIR OCCURRENCE, PROPERTIES AND ELIMINATION IN PRACTICAL AGRICULTURE.

BY

JOSHUA J. SKINNER, Ph.D.

Summary of the Results of Pot Experiments on the Effect of Aldehydes in Different Soils.

With experiments in pots salicylic aldehyde and vanillin had no, or only a slight, harmful action on the growth of plants in Hagerstown loam from Pennsylvania, Chester loam from Virginia, Chester loam from Maryland, Holston fine sandy loam from West Virginia, and Collington fine sandy loam from New Jersey.

The two aldehydes were harmful to plants grown in pots in Susquehanna clay loam from Maryland, sand from Florida, Cecil clay loam from North Carolina, Orangeburg sandy loam from Georgia, Cecil sandy loam from Georgia, Volusia loam from Ohio, and Norfolk sand from Alabama. Of these, the harmfulness was less in the Volusia silty loam. Salicylic aldehyde was applied in amounts of 200 pounds, and vanillin 400 pounds per acre.

When these soils were limed the harmfulness of the aldehyde was overcome altogether. Phosphate fertilizers ameliorated the harmfulness of salicylic aldehyde, and in some cases its effect was entirely overcome. Sodium nitrate lessened the action of vanillin. In soils fertilized with manganese the physiological action of both vanillin and salicylic aldehyde was changed.

The work with the twelve soils in pots further shows that aldehydes do not behave the same in all soils; in five of the soils it had no harmful effects, and in the other seven it was detrimental to growth. The five soils on which it had no harmful action—namely, the two Chester soils, the Holston fine sandy loam, the Hagerstown loam, and the Collington fine sandy loam—were productive field soils, which are in a high state of cultivation, have been manured well, and the general handling and crop management and drainage are good. By laboratory examination the soils were found to have good oxidizing power, which itself is an indication of a strong fertile soil. The seven soils on which the aldehydes caused a retardation in growth were not as good field soils as the five mentioned above. Their crop-producing power was less, and their general management and cropping were not so good. As a rule, the oxidizing power of these soils was poorer, which indicates an unhealthy condition.

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* Continued from page 480, Vol. 186, October, 1918.

From the field work, which is given in the next section, in which it is shown that the added aldehydes remained in the poor soils and decreased crop growth, and were changed or destroyed in the good soils, consequently having no serious detrimental effects, it is suggestive that the aldehydes were destroyed in the five good soils and were not in the seven poor soils.

In the soils in which the aldehydes produced a harmful effect on the plants lime and manganese greatly aided in lessening the effect of both vanillin and salicylic aldehyde. Phosphate ameliorated the harmfulness of salicylic aldehyde and nitrate of vanillin. As has been pointed out before, lime, nitrate, and manganese stimulate oxidation in most soils. Their beneficial action is probably due to a stimulation of this and other processes in the soil, which in turn act on the organic material and change or destroy it altogether, producing a better condition for plant growth. Aside from the action of this class of fertilizers in causing conditions in the soil preventing the formation or existence of such compounds, methods of cultivation, drainage, and crop management may have the same influence.

FIELD EXPERIMENTS WITH ALDEHYDES.

The field test of the aldehyde compounds were made in plots in the field. In all soil investigations experiments made under field conditions are considered more conclusive than pot tests or aqueous solution cultures. Field tests are influenced by a great many factors which cannot be controlled, and thus, from a strictly scientific point of view, are not as valuable as controlled tests in the greenhouse and laboratory. Yet experiments under field conditions with organic compounds and fertilizers will show the influence of such substances on soil fertility, and their bearing on practical agriculture can thus be determined.

The two aldehydes, salicylic aldehyde and vanillin, with which the pot studies were made, were tested in the field under varying conditions. These compounds were tested in the field on several soils, differing in geological origin and chemical and biological characteristics, and under different climatic conditions.

Inasmuch as it has been shown that the aldehydes have different effects in different soils, it was necessary in these field tests to demonstrate as to whether the added aldehydes remained as such in the soil, or whether they were destroyed or changed. It would not be expected that the organic substance, when added to a soil in which it was changed or destroyed by oxidation, bacteria, or other biological agencies, would have an effect on the crop grown thereon.

The field experiments were made on the Susquehanna silty clay loam at the United States Experimental Farm at Arlington, Va., in 1913, 1914, and 1915; on the Hagerstown loam at the Pennsylvania Experiment Station at State College, Pa., in 1914 and 1915, and on the Dunkirk clay loam at the Cornell Experimental Station at Ithaca, N. Y., in 1916.

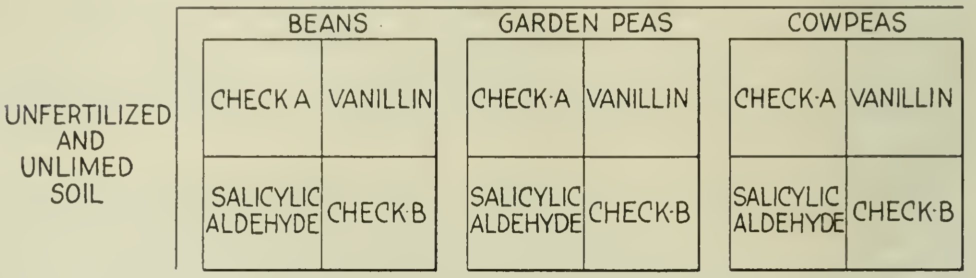
At the Arlington Farm in 1912 three crops were grown: cowpeas, garden peas, and string beans. In this year's experiment the vanillin and salicylic aldehyde were used in plots without fertilizers or lime. In the experiments in the following years at each of the locations cowpeas only were grown. The effect of the aldehydes, when used on soil fertilized with acid phosphate and sodium nitrate, and on limed soil, was determined on each of the soils. Fertilizers and lime influence the biological activities of the soil, and this, in turn, should have an effect on the organic constituents of the soil. A chemical study was made in each of the experiments to determine whether or not the added aldehydes remained as such in the soil during the growing period, or whether they were destroyed or changed.

Effect of Salicylic Aldehyde and Vanillin on Cowpeas, String Beans, and Garden Peas on Susquehanna Silty Clay Loam in 1913.

The effect of salicylic aldehyde and vanillin in soils under field conditions was tested on plots at the experiment farm of the Agricultural Department at Arlington, Va., and reported in 1914 and 1915 (58, 68). Three crops were grown; namely, cowpeas, string beans, and garden peas. The treated plot was adjoined on each side by an untreated plot growing the same crop. Each plot was 8¼ feet square, or one-fourth of a square rod; that is, one six-hundred-and-fortieth of an acre. The plan of the experiment is shown in Fig. 47.

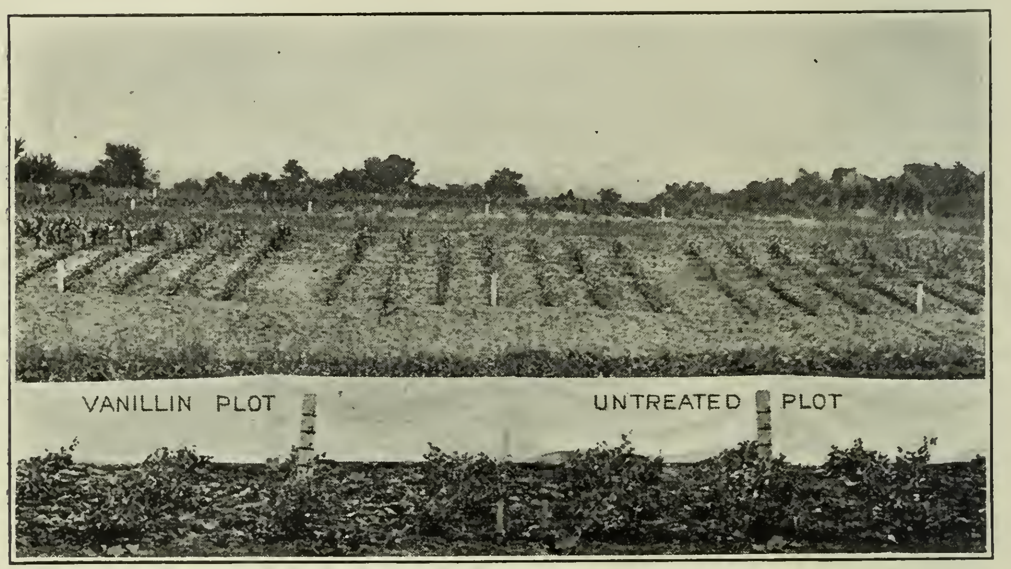
The soil on which these experiments were made is a heavy silty clay loam, low in organic matter. The ground is level and has surface drainage. The soil throughout these plots is uniform, and the results secured should not be considered as unduly influenced by irregularities due to non-uniformity of the soil in different plots. The soil is of an acid nature. The land was ploughed early in May and prepared for seeding to the above-named leguminous crops.

FIG. 47.



Plan of the aldehyde experiment, growing three crops, on the Susquehanna silty clay loam on the U. S. Experimental Farm at Arlington Va.

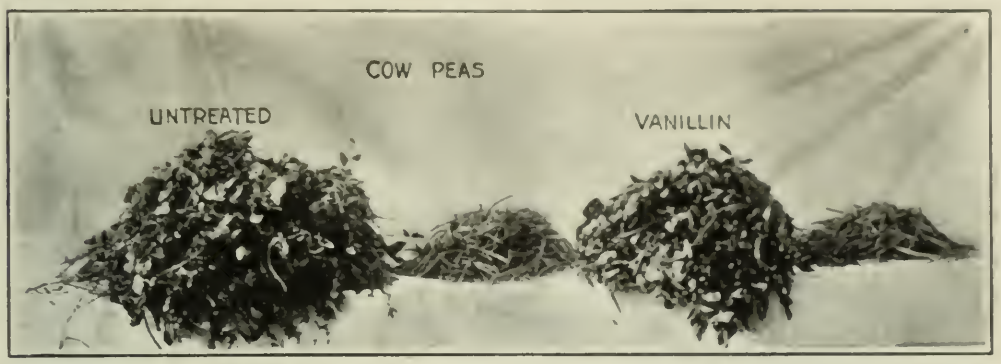
FIG. 48.



Effect of vanillin on cowpeas on Susquehanna silty clay loam (1913).

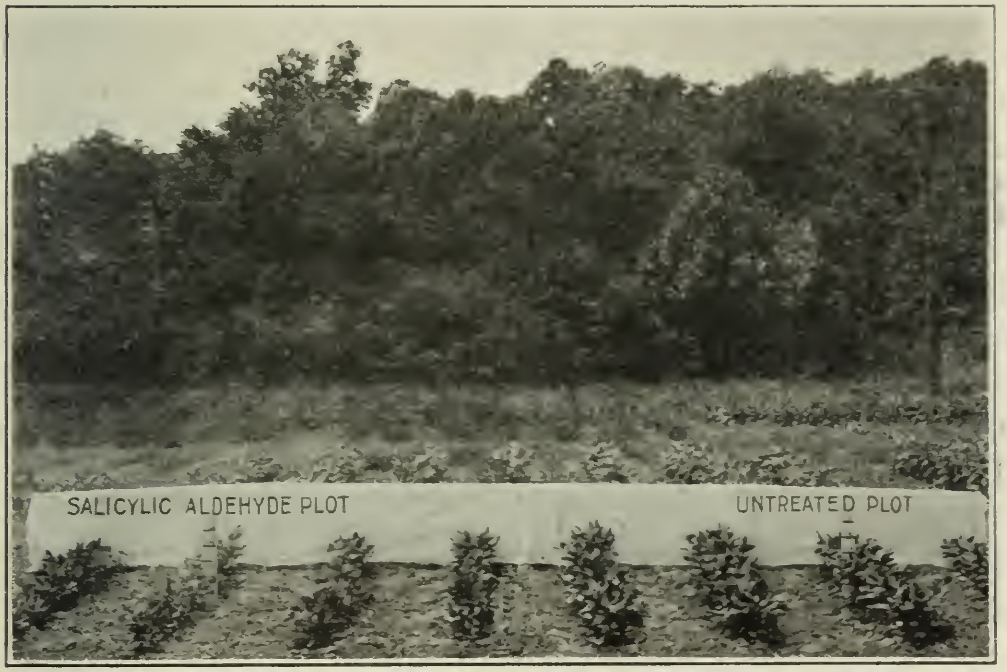
The salicylic aldehyde was applied at the rate of 105 pounds per acre, and the vanillin 285 pounds per acre. The salicylic aldehyde was applied in three portions. One-third of the total amount was applied May 20, one day before the seeds were planted; the second application was made after the plants were up on June 5, and the third on June 24. The vanillin was applied in four portions: May 20, May 28, June 5, and June 24. The material was applied by dissolving in water and pouring in a furrow near the rows of plants.

FIG. 49.



Yield of cowpeas, vines and pods on untreated plot and vanillin-treated plot on Susquehanna silty clay loam in 1913.

FIG. 50.

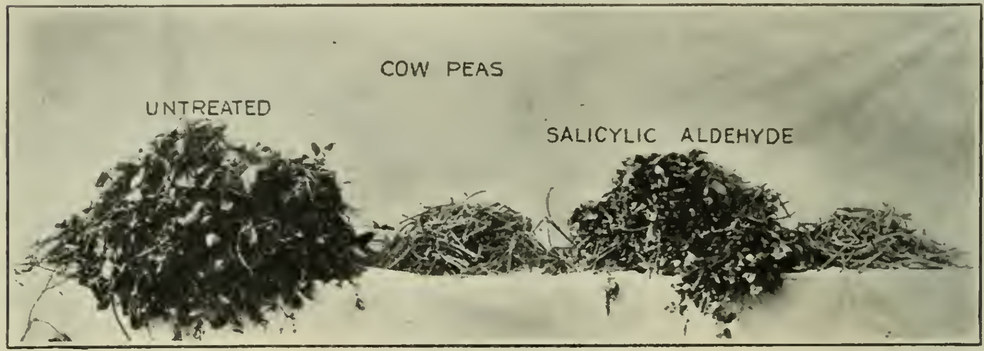


Effect of salicylic aldehyde on cowpeas in the field on Susquehanna silty clay loam in 1913.

The crops germinated uniformly. The effects of the aldehyde and vanillin were noticeable from the beginning. The growth was stunted and the plants grew slowly.

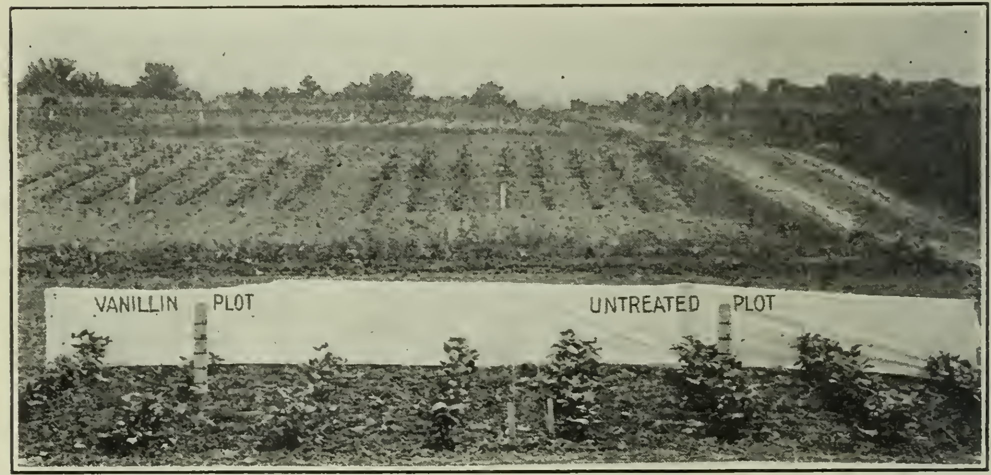
Cowpeas.—The cowpeas were planted May 27, 1913, and the crop was harvested September 7. The salicylic aldehyde and vanillin plots produced much smaller plants than the untreated soil. The vanillin-treated plants had a pale-green color and grew slenderer than their untreated checks. The appearance of the vanillin plants while growing is shown in Fig. 48, and of the harvested crop in Fig. 49. The salicylic aldehyde plants are shown in Fig. 50, and the harvested crop in Fig. 51. In these pictures it is seen that the aldehydes have reduced growth

FIG. 51.



Yield of cowpeas on check plot and on salicylic aldehyde treated plot on Susquehanna silty clay loam (1913).

FIG. 52.

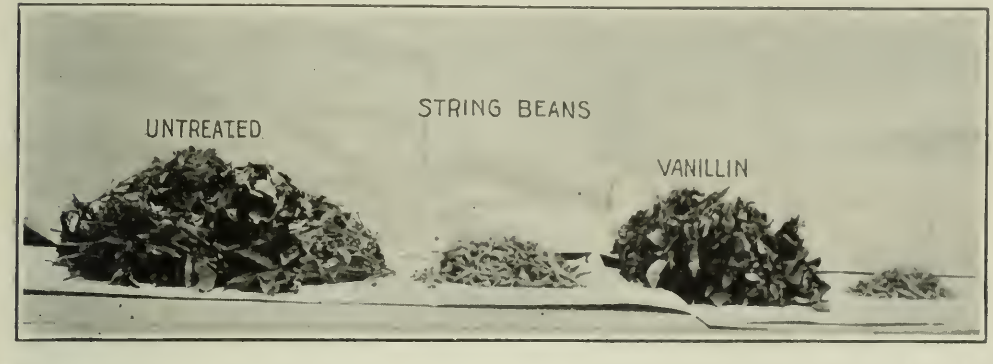


Effect of vanillin on string beans on Susquehanna silty clay loam (1913).

markedly, and it is evident that both compounds have interfered with the development of the plant. The effect became more marked as the plants approached maturity. The yields of green and cured hay and pods per plot and per acre (calculated) are given in Table XIII.

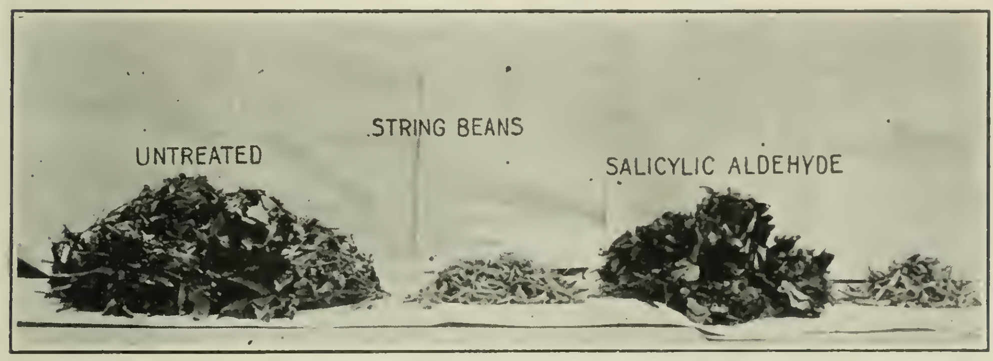
From the table it will be seen that the average yield of green vines plus pods on the check plots was 10.11 tons per acre, and on the salicylic aldehyde plot it was only 6.24 tons per acre, making a total decrease of crop 3.87 tons, or 38 per cent. There was a reduction of 50 per cent. in cured hay.

FIG. 53.



Yield of string beans, vines and pods, on untreated plot and vanillin plot on Susquehanna silty clay loam in 1913.

FIG. 54.



Yield of string beans, vines and pods, on check plot and salicylic aldehyde treated plot in 1913.

The vanillin plots produced 6.71 tons per acre of green vines plus pods, against 10.11 tons for the check; this is a reduction of 34 per cent. There was a reduction of 39 per cent. in cured hay.

String Beans.—The string beans did not appear to be as much affected in the early stage of their growth by salicylic aldehyde as did the cowpeas or garden peas. This was true even through the

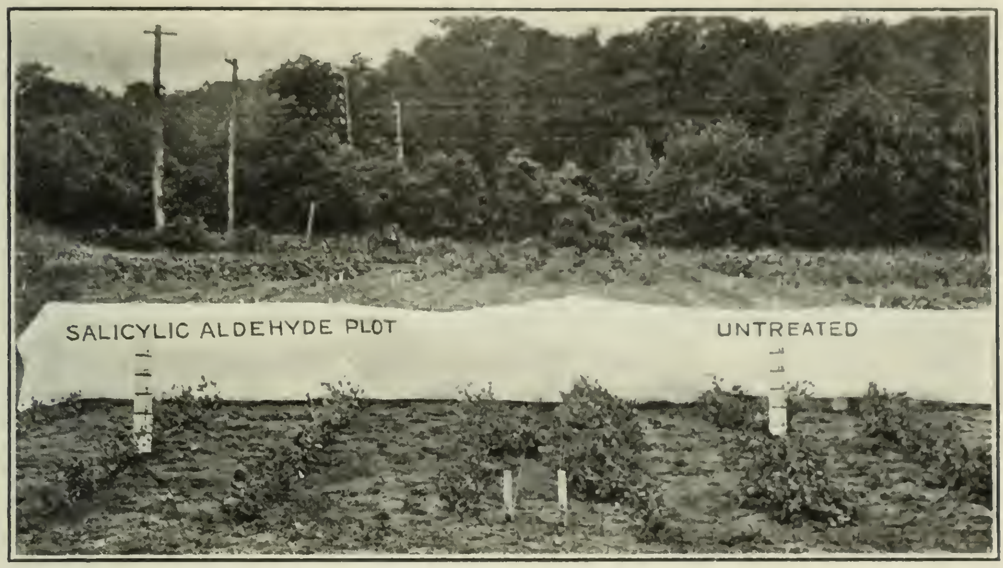
TABLE XIII.

Effect of Salicylic Aldehyde and Vanillin on Cowpeas, String Beans and Garden Peas in Susquehanna Silty Clay Loam in 1913.

	Cowpeas						String beans						Garden peas					
	Yield per plot			Yield per acre			Yield per plot			Yield per acre			Yield per plot			Yield per acre		
	Vines		Pods	Vines		Pods	Vines	Beans		Vines	Beans		Vines	Peas		Vines	Peas	
	Green	Cured		Green	Cured													
	Pounds	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*	*Pounds*	*Pounds*	*Pecks*
Check A........	28.00	10.0	6.6	8.96	3.20	2.11	3.55	1.90	4.75	2,272	1,236	190	1.72	1.66	4.50	1,101	1,062	180
Check B........	23.00	8.5	5.6	7.36	2.72	1.79	2.94	1.66	4.15	1,882	1,062	166	1.50	1.48	4.00	950	947	160
Average check...	25.5	9.3	6.1	8.16	2.96	1.95	3.24	1.78	4.45	2,072	1,149	178	1.61	1.57	4.25	1,030	1,004	170
Salicylic aldehyde.........	16.0	4.3	3.5	5.12	1.38	1.12	2.71	1.25	3.12	1,734	800	125	.52	.16	.43	333	102	17
Vanillin aldehyde	17.0	5.7	4.0	5.44	1.82	1.27	2.71	.55	1.50	1,734	352	56	1.12	1.14	3.00	717	730	120

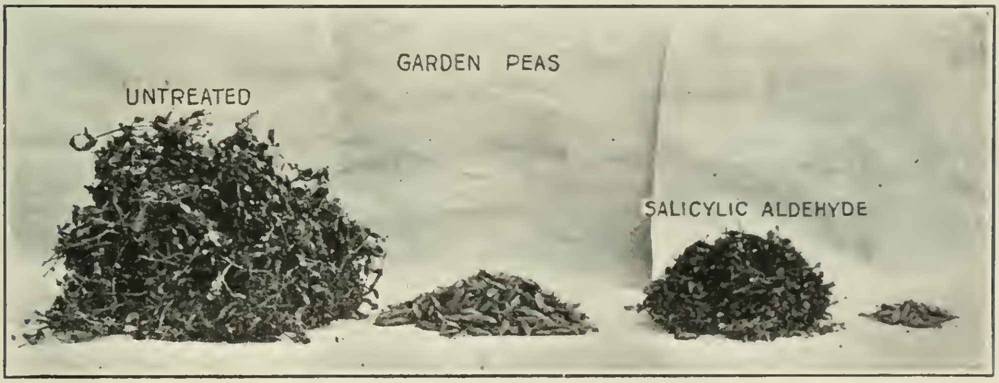
whole period of growth. The vanillin, however, affected them rather severely. As with the other crops, the growth was stunted. The beans were planted May 21, 1913, and were harvested on July 22. The effect of the vanillin on the growing crop is shown in Fig. 52, and the harvested crop is shown in Fig. 53. The harvested crop from the salicylic aldehyde plot is shown in Fig. 54. The yields are given in Table XIII.

FIG. 55.



Effect of salicylic aldehyde on garden peas in Susquehanna silty clay loam in 1913.

FIG. 56.



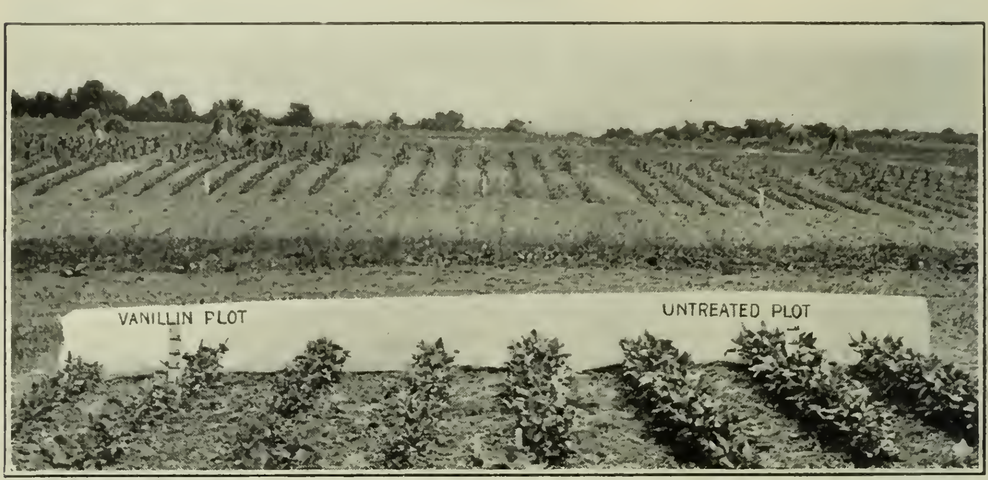
Yield of garden pea vines and pods on check plot and on salicylic aldehyde treated plot on Susquehanna silty clay loam (1913).

The average yield of vines plus beans per acre of the two check plots was 3219 pounds, against 2534 pounds per acre for the salicylic aldehyde plot, a decrease of 685 pounds of green matter per acre. The yield of marketable beans was reduced 53 pecks per acre.

The yield of vines plus beans from the vanillin plot was 2080 pounds per acre, a reduction of 34 per cent. There was a reduction of 122 pecks of beans per acre.

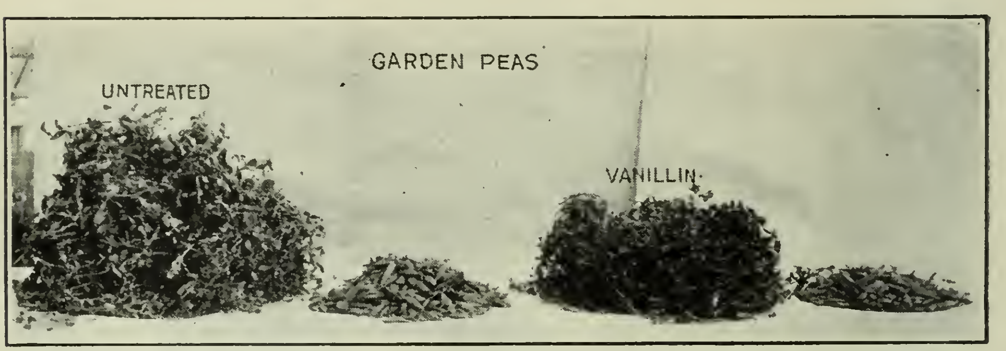
Garden Peas.—The garden peas had made their full growth by June 30, and they were cut on that date. Fruit formation was practically nothing on the salicylic aldehyde plot. The appearance of the untreated and treated plot on June 24 is shown in Fig. 55. The harvested crops are shown in Fig. 56.

FIG. 57.



Effect of vanillin on garden peas on Susquehanna silty clay loam (1913).

FIG. 58.



Yields of garden pea vines and pods on untreated plot and vanillin treated plot on Susquehanna silty clay loam in 1913.

The vanillin checked the growth of the peas from the very start, as it did the cowpeas and beans. The appearance of the growing plants is shown in Fig. 57, and of the harvested crop in Fig. 58. The yields are given in the Table XIII, along with those of the cowpeas and string beans.

The yield of total plant material, vines and pods, was 2034 pounds per acre as an average of the untreated checks, as compared with 435 pounds on the salicyclic aldehyde plot, a decrease of 1599 pounds. The marketable crop—that is, the peas in shell—was depressed from 1004 pounds per acre to 102 pounds, or 90 per cent.—practically a total failure.

As seen from the table, the yield of the vanillin plot is far below the checks. There was a reduction of 30 per cent. in vines and 20 per cent. in marketable peas, due to the presence of vanillin.

Presence of Aldehydes and Their Effect in the Soil Six Months After Application.

The question of the length of time the salicylic aldehyde and vanillin would persist in the Arlington soil and have an influence on its crop-producing power has also been investigated by a chemical study in the laboratory and by plant physiological tests. Samples of soil for these purposes were obtained from the plots the last of November, six months after the substance was applied, and after a crop had been matured. The soils were examined for salicylic aldehyde and vanillin by the method previously described in this paper (61). The three treated plots in each case were found to still contain the added vanillin or salicylic aldehyde.

The existence of the harmful compounds in the soil was also shown in another way by growing wheat in the greenhouse in the soil in paraffined wire pots, using the respective soils from the salicylic aldehyde-treated plots and from the vanillin-treated plots and the check plots. Two pots, with six plants each, were used of each soil. The plants grew from December 11, 1913, to January 6, 1914. The results are given in Table XIV.

TABLE XIV.

Growth of Wheat in Soil Taken from the Field Plots Six Months After Treatment With Salicylic Aldehyde and Vanillin.

Crop grown previously in the field	Growth of wheat plants on			Relative growth check = 100	
	Soil from check plot	Soil from salicylic aldehyde plot	Soil from vanillin plot	Soil from salicylic aldehyde pots	Soil from vanillin pots
	Grammes	*Grammes*	*Grammes*		
Cowpeas...........	1.48	1.18	1.09	80	74
String beans........	1.54	1.11	1.10	72	71
Garden peas........	1.47	1.22	1.10	83	75

A similar experiment was made with these soils, except that the crops grown in the pots were identical with those which had grown in the field the preceding season; that is, cowpeas were grown on the cowpea soil from the check plot and from the salicylic aldehyde and vanillin plots, string beans on the string-bean soil from both the check and treated plots, and garden peas on the garden pea soil from the check and treated plots. Two pots were used in each case, and two plants were grown in each pot. The vegetative growth made in this experiment is given in Table XV.

TABLE XV.

Growth of Cowpeas in Soil from the Cowpea Field Plots, String Beans in Soil from the String Bean Field Plots, and Garden Peas in Soil from the Garden Pea Field Plots, Collected Six Months After Treatment With Salicylic Aldehyde and Vanillin.

Crop grown previously in the field	Green weight of plants upon			Relative growth	Check 100
	Soil from untreated plot	Soil from salicylic aldehyde plots	Soil from vanillin plots	Salicylic aldehyde pots	Vanillin pots
	Grammes	*Grammes*	*Grammes*		
Cowpeas	4.30	3.80	3.05	88	71
String beans	7.80	7.20	7.35	92	94
Garden peas	5.60	4.30	4.00	77	71

The tables show that the salicylic aldehyde and vanillin treated soils were still harmful to the respective crops in samples collected six months after the application of the aldehydes and after it had produced the same crop in the field.

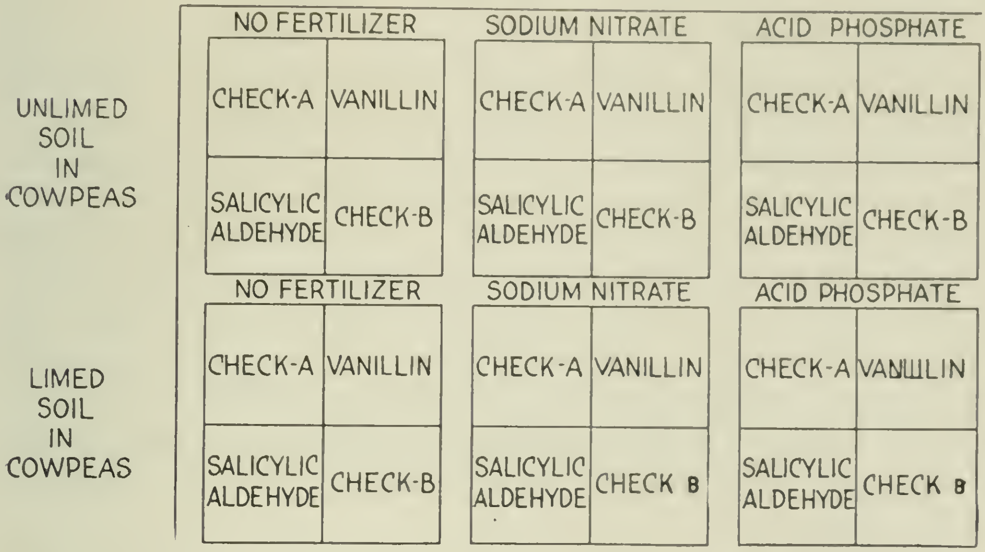
The data here presented show that the salicylic aldehyde and vanillin persisted in the soil on which this experiment was made, at least throughout the growing season. This is demonstrated, first, by the lessened yield of the crop, for if the added material had been destroyed in the soil the plants would not have been injured; second, by the demonstration of its presence at the end of the growing season by means of chemical methods; and third, by the lessened growth of crops in pots containing the treated field soil, six months after the application of the aldehydes in the field.

The next step in this investigation leads us into a study of the action of aldehyde in field soils of different characteristics, the persistence or destruction of aldehyde in different soils, the means by which the substance is destroyed in soils, and the action of fertilizers on the physiological effect of the compounds in soils.

The Action of Fertilizers on Aldehydes in Susquehanna Silty Clay Loam.

The experiments here reported were made on the Arlington Farm in 1914 and 1915. Unlike the experiments just recorded, only one crop, cowpeas, was grown, but the soil treatments were enlarged upon so as to determine the effect of soil aldehydes in soil to which lime and certain fertilizers had been added. Slightly larger amounts of both vanillin and salicyclic aldehyde were used in this test than in the test with the three crops in 1913. At that time vanillin was used at the rate of 285 pounds per acre and salicyclic aldehyde at the rate of 105 pounds per acre. In 1914 and 1915 vanillin was used at the rate of 300 pounds per acre and salicyclic aldehyde at the rate of 150 pounds per acre. A similar experiment was made in 1914 and 1915 on the Hagerstown loam at the Pennsylvania Experiment Station. The plan of the experiment used on both soils is shown in Fig. 59.

Fig. 59.



Plan of the aldehyde—fertilizer experiment on the Susquehanna silty clay loam on the U. S. Experimental Farm at Arlington, Va., and on the Hagerstown loam at the Pennsylvania Experiment Station.

Both vanillin and salicyclic aldehyde are added to the soil, (1) without fertilizers, (2) with sodium nitrate, (3) with acid phosphate. The aldehydes are also applied to limed soil, with no fertilizers, with sodium nitrate, and with acid phosphate. An examination of the plan of the experiment will show the arrangement of the checks. It is seen that there are two unfertilized checks to compare with the vanillin and salicyclic aldehyde plots. There are two check plots treated with sodium nitrate to compare with the plots which received vanillin or salicylic aldehyde in addition to sodium nitrate; and there are two check plots which received phosphate to compare with the plots which received vanillin or salicylic aldehyde in addition to the acid phosphate. These treatments are repeated on an adjoining strip of ground which had been previously limed at the rate of two tons per acre.

In the Arlington experiment each of these blocks of four plots as shown in the diagram is one square rod, making each plot one six-hundred-and-fortieth of an acre.

Sodium nitrate was added in amounts of 180 pounds per acre and acid phosphate at the rate of 360 pounds per acre. The method of applying these substances was to apply one-third of the total amount before planting, one-third when the plants were about four inches high, and the remaining one-third about four weeks after the second application. The vanillin and salicylic aldehyde were dissolved in water and thoroughly worked into the soil. The fertilizers were applied at the same time and were broadcasted over the plot and raked in. The total amount of lime on the limed plots was applied two weeks before the experiment was started. This was used at the rate of two tons per acre. It was spaded in and well mixed with the soil to a depth of eight inches.

The Susquehanna silty clay loam on which this experiment was made is naturally unproductive. It can be made to produce fair crops by manuring heavily with green manures or stable manure, and it responds to fertilizers well when limed. It is acid, and when the surface soil is neutralized it becomes acid again within a few months, whether growing crops or fallowing.

The Results Obtained in 1914.

Four rows of cowpeas were planted on each plot, May 20, 1914. The Early Buff peas were used, which is an early maturing variety. The seeds germinated well and came up uniformly. In the early stages of growth the plots showed slight differences, and notes taken July 16 are here given.

Unfertilized Section.—The two check plots have made a growth of about 22 inches in height. The plants have a good dark-green color; they are beginning to put out runners. No blooms are appearing.

The plants on the vanillin-treated plots are stunted in growth. They are one-half to one-third the size of the check-plot plants; average height about 12 inches. There are no runners and no blooms. The vines have a pale-yellow color and do not appear as hardy and thrifty as the check-plot plants. The leaves are distorted, are curled unnaturally, and the ribs are more prominent.

The salicylic aldehyde plot has produced plants of about the size of, or slightly smaller than the vanillin plot. The average height is about 10 inches. They have a lighter green color than check-plot plants, but are not as pale green as the vanillin-plot plants.

Sodium Nitrate Section.—The sodium nitrate check-plot plants are about the size of the plants in the check plots of the unfertilized section. They have a height of 20 to 22 inches. The color is good dark green. A few runners and a few blooms are cut.

The vanillin-plot plants are almost as good as the sodium-nitrate-check plants; they are a little smaller. The color is good, and there is no sign of distorted or disfigured leaves. The average height is 18 to 20 inches. A few runners are starting.

The salicylic-aldehyde-plot plants are smaller than the check plants, about the size of the salicylic aldehyde plants in the no-fertilizer section.

Acid Phosphate Section.—The plants in the acid phosphate check plots are the best of the series. Their height is 28 to 30 inches. The color of the vines is a dark green, and they are healthy and thrifty. The plants are full of runners and have some blooms.

The vanillin-plot plants are much smaller than the checks. The difference between the check plot and the vanillin plot of the acid phosphate section is about as great as the difference between the check plot and the vanillin plot of the no-fertilizer section. There are no runners and no blooms. All the plots of the acid phosphate section are better than the no-fertilizer section.

The growth in the salicylic aldehyde plot is almost as good as in the check plots. The plants have a good color, are thrifty and healthy. There are a few runners.

Limed Soil, No-fertilizer Section.—The plants have made an excellent growth, they are tall and bushy, and are full of runners and blooms. They are twice the size of the unlimed checks. The color of the foliage is a deep-green color.

The vanillin-plot plants are about the size of the checks; they are full of runners and blooms. There is no indication of a harmful effect.

The growth on the salicylic aldehyde plot is not quite so good as the check. The color is good.

Limed Soil, Sodium Nitrate Section.—The check-plot plants are a little better than the limed unfertilized checks, and growth is bulky and thick.

The vanillin plot is slightly smaller than the check in growth, and the runners are not so numerous. The color is good, and there are no unnatural leaves.

The growth in the salicylic aldehyde plot is about the same as in the check plot. There are lots of runners and blooms.

Limed Soil, Acid Phosphate Section.—The growth on the check plots is better than on the limed no-fertilizer check.

The vanillin-plot plants are slightly smaller than the check; the growth is good and plants healthy.

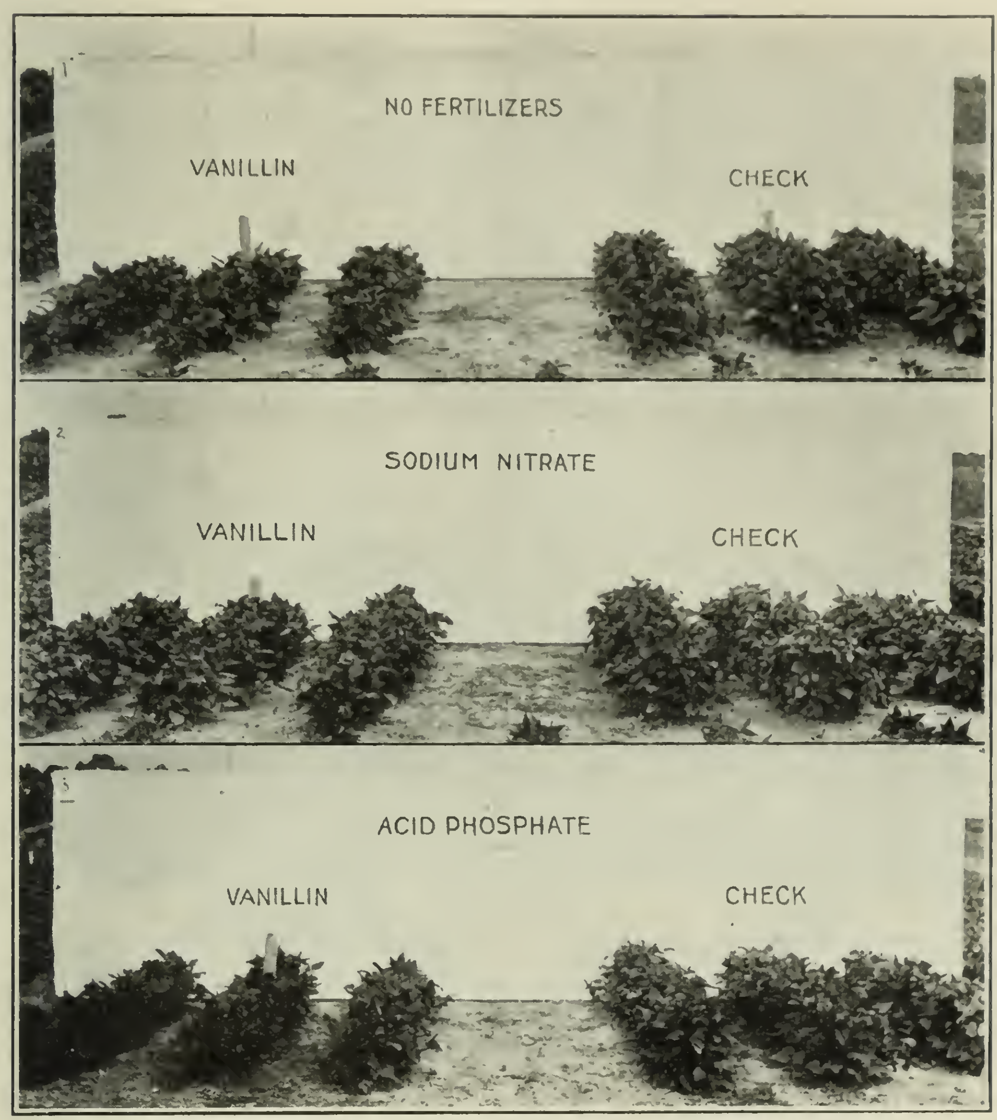
On the salicylic aldehyde plot the growth is about the same as on the check plots.

There is very little difference between any of the plots on the limed soil. At this stage of the growth the aldehydes are apparently having no effect in the limed soil.

Photographs were taken July 16 and are reproduced in Figs. 60, 61, 62, and 63. The marked differences in growth on the vanillin and salicylic aldehyde plots are apparent. In Fig. 60 are shown the effect of vanillin on cowpeas in the Susquehanna silty clay loam, the effect of vanillin on the soil fertilized with sodium nitrate, and its effect on the soil fertilized with acid phosphate. As seen in the top cut, the vanillin plants on the left have made a much smaller growth than those on the check plot on the right. In the middle cut the vanillin plot on the left fertilized with sodium nitrate has made almost as good growth as its check plot on the right. The sodium nitrate has overcome to a great extent the effect of the vanillin. In the soil fertilized with acid phosphate the growth, as shown in the bottom cut, is not nearly so good on the vanillin plot on the left as in its check plot on the right. The vanillin has retarded growth as much on the acid phosphate plots as on the unfertilized soil. The harvested crops are shown in Fig. 61.

In Fig. 62 are shown the effects of salicylic aldehyde on cowpeas grown on unfertilized soil, on soil fertilized with sodium nitrate, and with acid phosphate. In cut 1 the plants on the left, which received the salicylic aldehyde, are much smaller than the check on the right. This is also true with the growth on the soil fertilized with sodium nitrate, cut 2. Here again the salicylic-

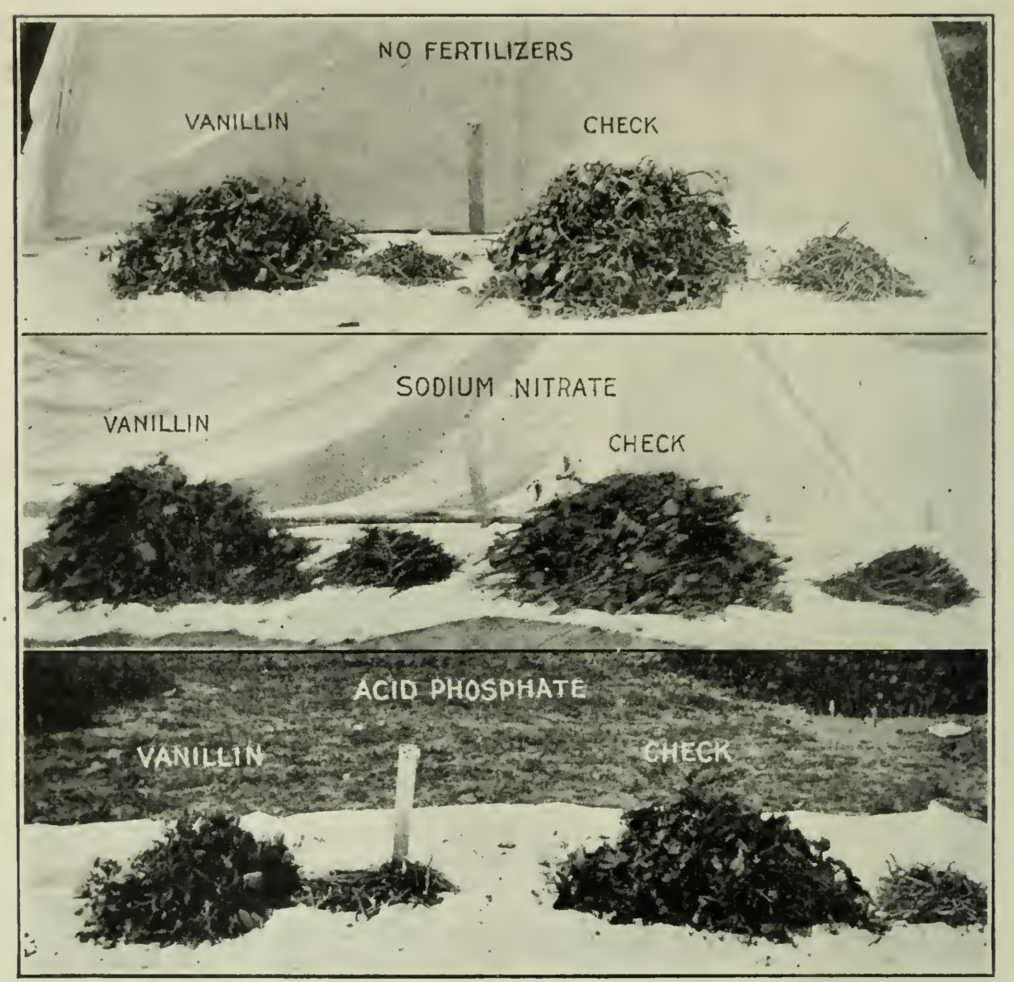
FIG. 60.



Effect of vanillin on cowpeas in the Susquehanna silty clay loam at Arlington, Va. (1914).

aldehyde-treated plants on the left are much smaller than the check plants on the right. The growth on the soil fertilized with acid phosphate is almost as good on the salicylic aldehyde plot as on the check, as shown in cut 3. It seems from this that acid phosphate has an influence in ameliorating the harmful effect of salicylic aldehyde in this soil. The harvested crops are shown in Fig. 63.

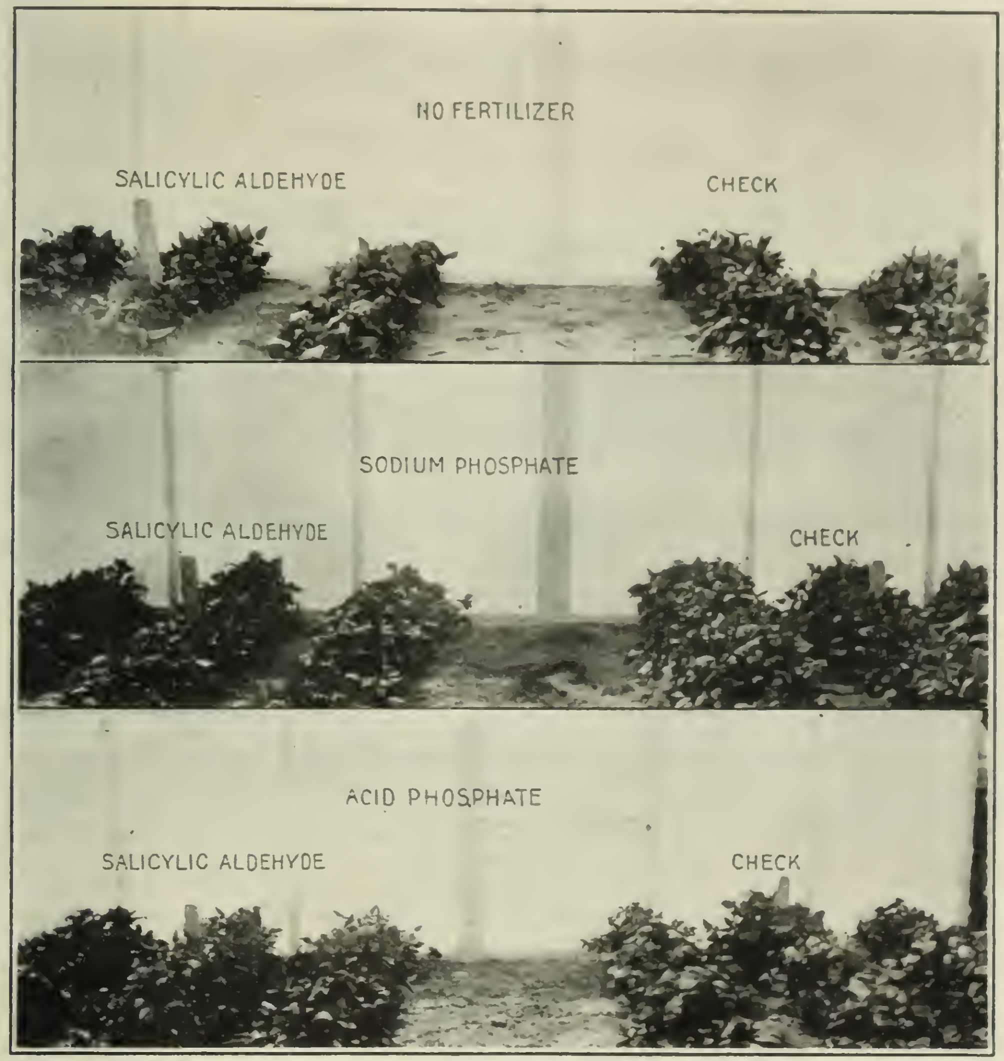
FIG. 61.



Yield of cowpeas, vines and pods, as affected by vanillin. Grown on the Susquehanna silty clay loam at Arlington, Va. (1914).

The cowpeas were harvested August 19. The plants had made their full growth and the seed was ripening. The peas on the lime section were more mature than on the unlimed; the bottom leaves were turning and some were beginning to fall. The vanillin and salicylic aldehyde plots were slower in maturing than their checks. The cowpeas were picked from the vines before they were cut and their weight in pod taken separately. The green weight of the vines was taken, and then the vines were spread back upon the plot and allowed to dry. The dry weight of the cured cowpea hay was taken August 24. The results for each plot are given in Table XVI.

FIG. 62.



Effect of salicylic aldehyde on cowpeas in the Susquehanna silty clay loam at Arlington, Va. (1914).

TABLE XVI.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas Grown in the Field on Susquehanna Silty Clay Loam in 1914, and the Action of Fertilizers in Modifying Their Effect (Weights Given in Pounds Per Plot).

Treatment	Unlimed soil					Limed soil				
	Green weight			Dry weight		Green weight			Dry weigh	
	Vines	Pods	Relative total weight	Hay	Relative weight	Vines	Pods	Relative total weight	Hay	Relative weight
No-fertilizer section:										
Check A	21.50	6.00	100	10.00	100	26.00	9.50	100	15.00	100
Check B	22.00	6.75		11.00		24.50	8.75		13.75	
Vanillin	13.50	4.25	67	7.50	71	23.00	9.75	107	14.25	99
Salicylic aldehyde	10.50	3.75	59	5.75	55	18.50	7.00	77	10.75	71
Sodium nitrate section:										
Check A	24.50	7.25	100	12.50	100	27.50	9.75	100	15.75	100
Check B	23.25	7.50		12.25		25.75	8.50		15.00	
Vanillin	21.00	6.75	91	11.50	91	27.75	9.25	101	14.75	96
Salicylic aldehyde	15.25	4.00	54	8.75	70	22.00	7.50	83	12.50	82
Acid phosphate section:										
Check A	25.50	7.75	100	14.25	100	29.25	9.50	100	15.50	100
Check B	25.00	7.25		13.75		32.00	10.00		16.25	
Vanillin	19.00	6.00	80	10.00	71	29.00	8.75	90	14.75	93
Salicylic aldehyde	23.75	7.25	97	13.00	93	29.75	9.25	95	15.50	98

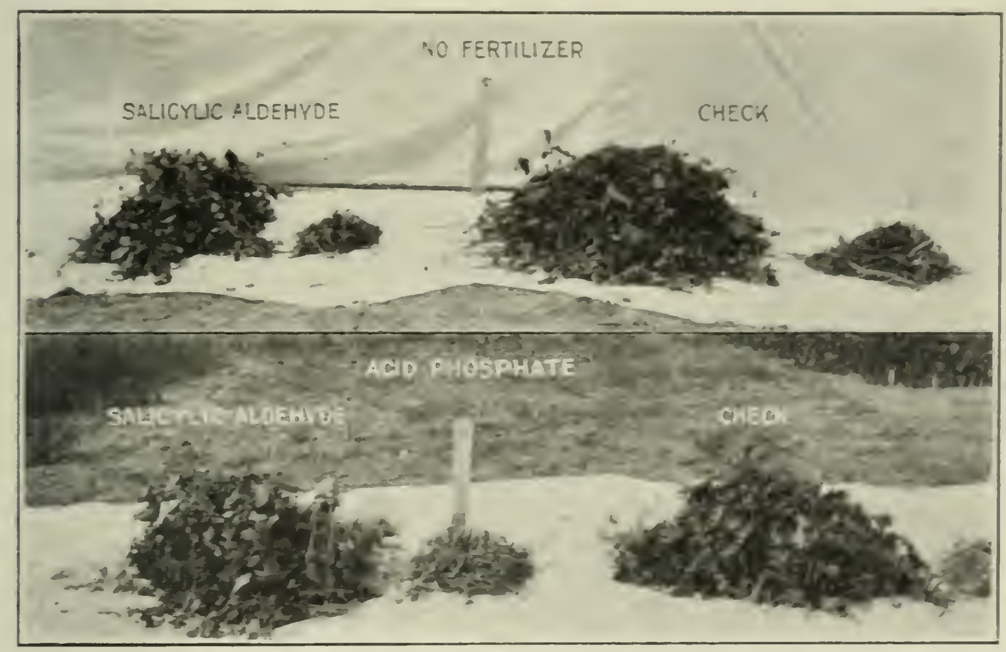
An examination of the table shows that the check plots were fairly uniform; the yields on these duplicate plots were very near the same. An average of the two checks will be taken here in comparing the yields of the treated plots. Considering first the unlimed soil, it is seen that vanillin and salicylic aldehyde reduced growth very much in the unfertilized soil. As shown in the third column of the table, the green weight was reduced by vanillin from 100 to 67, or 33 per cent., and by salicylic aldehyde from 100 to 59, or 41 per cent. The weight of cured hay was reduced by vanillin from 100 to 71, a reduction of 29 per cent., and by salicylic aldehyde from 100 to 55, a reduction of 45 per cent.

In the plots fertilized with sodium nitrate the vanillin reduced the growth only 9 per cent. in both green weight and dry weight; that is, from 100 for the check to 91 for the vanillin-treated plot. The salicylic aldehyde reduced growth in green weight from 100 for the check to 54, a 46 per cent. decrease, and in dry weight from 100 for the check to 70, a reduction of 30 per cent.

In the plots fertilized with acid phosphate the vanillin reduced the green weight from 100 for the check to 80, a reduction of 20 per cent., and the dry weight from 100 to 71, a reduction of 29 per cent. The salicylic aldehyde reduced the green weight from 100 for the check to 97, a reduction of only 3 per cent., and in cured hay from 100 to 93, a reduction of 7 per cent.

Both of these compounds, then, had a harmful effect in this soil. The harmfulness of vanillin was partly overcome by sodium nitrate, but was just as harmful with acid phosphate, and the bad effects of salicylic aldehyde were partly overcome by acid phosphate, but sodium nitrate had no such helpful function.

FIG. 63.



Yield of cowpeas, vines and pods, as affected by salicylic aldehyde. Grown on the Susquehanna silty clay loam at Arlington, Va. (1914).

Considering now the limed soil, given in the last half of the table, it is seen that the vanillin had no harmful effects in the unfertilized soil. The salicylic aldehyde reduced growth in green weight from 100 for the check to 77, or a reduction of 23 per cent., as against 41 per cent. for the unlimed plot. In dry weight there was a reduction of 29 per cent., as against 45 per cent. for the unlimed plot.

In the sodium nitrate plots the growth in the vanillin plot was approximately the same as in the checks. The salicylic aldehyde reduced growth from 100 for the check to 82, a reduction of 18 per cent. in both green and dry weight, and practically the same in dry weight.

In the acid-phosphate-treated soil the vanillin plot reduced growth in green weight from 100 for the check to 90, and in dry weight from 100 to 93. This apparent harmful effect of vanillin in the limed soil with acid phosphate is probably accidental, as in the other plots where lime was used no harmful effects were observed.

With the amount of acid phosphate used increased acidity is out of the question, as there was an excess of lime applied and the plots were neutral throughout the season, as shown by chemical tests. In the acid phosphate plot the salicylic aldehyde reduced growth very little; in fact, no difference was observable during the period of growth, but in green weight the aldehyde plot produced 5 per cent. less than the check, while in dry weight there was a reduction of only 2 per cent.

It is seen, then, that in the limed soil vanillin had practically no harmful effect. The harmfulness of salicylic aldehyde was greatly lessened, and with acid phosphate and lime together practically no harmful effects were observed.

The Results Obtained in 1915.

The experiment just described was repeated on the same plots in 1915, and in every detail is a duplicate of the former experiment. The seeds were planted May 29, and by July 7 the plots were showing considerable differences. Again this year the vanillin and salicylic aldehyde on the unfertilized soil checked growth very much. In the soil fertilized with sodium nitrate the harmfulness of vanillin was overcome to a certain extent, and, as before, the harmfulness of salicylic aldehyde was lessened by acid phosphate fertilization. The limed plots again produced better growth than the unlimed, and the effect of the aldehydes was only slight. The crop was harvested August 27. This year the peas were not picked from the vines; the green and dry weights of the vines and peas together are given in Table XVII.

TABLE XVII.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas Grown in the Field on Susquehanna Silty Clay Loam in 1915, and the Action of Fertilizers in Modifying their Effects (Weights Given in Pounds Per Plot).

Treatment	Unlimed soil				Limed soil			
	Green weight		Dry weight		Green weight		Dry weight	
	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight
No-fertilizer section:								
Check A	32.0	100	14.0	100	46.0	100	21.0	100
Check B	34.0		16.0		44.0		20.0	
Vanillin	26.0	79	11.5	77	47.0	104	21.0	102
Salicylic aldehyde	24.5	74	11.0	73	41.0	91	18.5	90
Sodium nitrate section:								
Check A	42.0	100	21.5	100	46.0	100	20.5	100
Check B	39.5		18.5		44.5		19.0	
Vanillin	39.5	97	18.0	90	44.5	85	18.5	93
Salicylic aldehyde	34.5	85	16.0	80	45.0	100	18.5	93
Acid phosphate section:								
Check A	36.0	100	20.0	100	47.0	100	20.0	100
Check B	33.5		18.5		44.0		17.0	
Vanillin	31.5	91	15.0	80	43.0	94	18.5	100
Salicylic aldehyde	32.5	93	17.0	88	44.5	98	17.0	92

By an examination of the table it is seen that the data, in the main, support the results secured in the former years. That salicylic aldehyde and vanillin are harmful in this soil and that lime overcomes the effect of both compounds, and that sodium nitrate lessens the harmful action of vanillin, and acid phosphate that of salicylic aldehyde, seem well established.

Examination of the Soils for Aldehyde at the End of the Growing Period.

Samples of soil were taken from each plot August 24, 1914, the day on which the crops were harvested, for the purpose of examining them in the laboratory to ascertain if the vanillin and salicylic aldehyde were still present in the soil.

An acidity test made of the various plots showed that each of the unlimed plots was acid and all of the limed plots were neutral or slightly alkaline.

Soil from each plot was examined for aldehydes by the method already described in this paper and in Bulletin 88, Bureau of Soils, and in Bulletins 108 and 164 of the United States Department of Agriculture. In this work with vanillin- and salicylic-aldehyde-treated soils it was merely determined as to whether aldehyde material was still present or not.

Soil from the untreated plots, subjected to the above-described process, was found to contain no aldehydes. The plot to which vanillin had been added, but no fertilizers, was found to contain aldehyde. After making the color reactions the remaining portion of the residue was dissolved in water and used as a culture solution for the growth of wheat seedlings. Seedlings were grown in distilled water without the residue as a check. Growth was reduced by the extracted substance 30 per cent., showing it to be very harmful to wheat plants.

No aldehyde was found in the soil from the plots treated with vanillin and sodium nitrate, or with vanillin and acid phosphate. The ether extract secured in the process of the isolation of aldehyde usually gives a residue of some kind. The residue secured from these two soils, when dissolved in distilled water, showed no harmful effects on wheat plants, so, whatever this residue was, it was not harmful to plants, as was that from the unfertilized plot, which by the color reactions showed it to contain aldehydes.

Soils from the plots to which salicylic aldehyde, salicylic aldehyde and sodium nitrate, and salicylic aldehyde and acid phosphate were added were examined, and each was found to contain aldehyde. In each case there was a good amount of residue from the ether extract, which gave the color reactions for aldehyde. In the plant test the residue from the salicylic aldehyde plot reduced growth 25 per cent.; from the salicylic aldehyde and sodium nitrate plot, 7 per cent.; and from the salicylic aldehyde and phosphate plot, 11 per cent. The material extracted from each of these soils was harmful; there was considerably more effect from the substance from the salicylic aldehyde unfertilized plot than from the other two.

No indications of the presence of aldehydes were found in any of the soils from the limed plots, which would tend to show that the added vanillin and salicylic aldehyde did not remain in the soil as such during the growing season. Lime might either have a direct chemical effect or stimulate oxidation and life-processes in the soil, which would cause such substances as aldehydes to be oxidized or otherwise changed. The vanillin and salicylic aldehyde had very little effect on the crop in the limed plots, which is in harmony with the fact that they were not found to remain in the soil under these conditions.

It might also be pointed out that the sodium nitrate partly overcame the effects of vanillin, and at the end of the growing season no vanillin was found in the soil, which would indicate that sodium nitrate fertilizer made conditions such that vanillin would not exist in this soil. Neither was vanillin found at the end of the experiment in the soil to which acid phosphate had been added, yet the vanillin had affected the growth, which may have occurred when the material was first added to the soil.

The salicylic aldehyde with and without fertilizers was found to remain in the unlimed soil throughout the growing season; however, the acid phosphate greatly lessened its effects on growth. These methods for the isolation of aldehydes are not quantitative, and it may be that only a small part of the aldehyde remained in the soil, while most of it was changed or destroyed and did not long remain to influence plant growth.

At the end of the crop season in 1915 the soils from each plot were also examined for aldehydes. Of the unlimed plots to which vanillin had been added, aldehydes were found to be present in both the no-fertilizer vanillin plot and in the acid phosphate vanillin plot. The material isolated from both of these soils was harmful to wheat seedlings in distilled water. No aldehyde was found in the vanillin plot which had been fertilized with sodium nitrate.

Each of the unlimed plots to which salicylic aldehyde had been applied was found to contain aldehyde at this time, and this isolated aldehyde material proved to be harmful to wheat plants in each case.

No aldehydes were found in any of the plots on the limed soil, showing the complete disappearance of these substances under the influence of lime.

In both 1914 and in 1915 vanillin and salicylic aldehyde added to the unlimed soil remained as such to affect crop growth throughout the growing season. In both years the aldehydes had only a slight effect on crop growth in the limed soil, and now, when the soil is examined at harvesting time, none is found to have persisted in the soil throughout the season.

In both 1914 and 1915 vanillin added to the soil fertilized with sodium nitrate was not found to be present several months after its application. It appears that sodium nitrate acts in the soil in such a way as to destroy vanillin or change it to more highly oxidized compounds that are not harmful to plant growth.

The behavior of these compounds as to their effect on crop growth and as to their permanency in another type of soil which is entirely different in character and in a different climate will be interesting to compare with the experiments at Arlington. It has been shown that even on the Arlington soil under different fertilizing practices the substances behave differently. The experiments on the Hagerstown loam in Pennsylvania were conducted to study these effects on a more fertile soil.

Before presenting the results obtained on this more fertile soil, having a higher oxidation capacity, it will be well to present some experiments and observations made as to the influence of this oxidation factor as determined on the differently treated and differently fertilized plots on the Arlington soil. The experiments seem to indicate a certain relationship between increased oxidation on the one hand and decreased toxicity and destruction of aldehydes on the other.

Effect of Vanillin and Salicylic Aldehyde on the Oxidation of the Soil.

Oxidation by plants is a factor which has considerable bearing on soil fertility. By oxidation the plant may change the organic matter in the medium in which it is growing. The oxidizing power of plant roots grown in extracts of productive soils is greater than that of plant roots grown in extracts of unproductive soils. The presence of vanillin and cumarin in a culture solution greatly checked oxidation by the plant roots (45). Soils themselves have oxidizing power, and the degree of oxidative power which a soil possesses varies with the soil. As a rule, soils that are known to be productive have strong oxidative power and poor soils have little or no oxidative power. Whatever decreases oxidation in soils tends also to bring about conditions which decrease growth, and the factors which favor oxidation are the factors which favor soil productivity.

The oxidative power of the silty clay loam at Arlington is relatively poor as compared to other agricultural soils, and the oxidation of the Hagerstown loam at State College, Pa., on which the aldehyde experiments were also made, is very good; in fact, the oxidation in this soil was found to be among the best of a long list of soils tested (59). Oxidation studies were made of the soils on the Arlington plots to determine the effect of added vanillin and salicylic aldehyde.

For this purpose samples were taken July 16, 1915, before the last application of aldehydes was made; July 23, seven days after the last application, and on November 19, about two and one-half months after the crops were harvested and four months after the last application of aldehydes. The method used in testing the oxidative power of these soils is the same as that described in Bulletin 56 of the Bureau of Soils. The method, in brief, consists of shaking 20 grammes of soil in a water solution of aloin, allowing to settle and adding 50 c.c. of alcohol to flocculate the soil and to extract the oxidized aloin. The solution is then centrifuged, the supernatant liquid poured off, and the depth of color in the solutions compared by means of a colorimeter.

The oxidation of the untreated plot and the effect of sodium nitrate, acid phosphate, and lime on the oxidation of the soil will first be considered. The relative oxidation of the fertilized plots as compared with the untreated soil is given in Table XVIII.

TABLE XVIII.

Effect of Fertilizers and Lime on Soil Oxidation in Susquehanna Silty Clay Loam.

	Relative oxidation			Average oxidation
	July 16	July 23	November 19	
Soil untreated	100	100	100	100
Soil + sodium nitrate	131	127	121	126
Soil + acid phosphate	109	95	99	97
Soil + lime	138	134	100	124
Soil + lime + sodium nitrate	147	144	121	137
Soil + lime + acid phosphate	131	121	81	111

The oxidative power of the samples taken July 16 are given in the second column of the table; in the third column is given the oxidation of the soil July 23, and in the fourth column the oxidation on November 19. In the last column the averages of the three periods are given.

It is seen from the table that sodium nitrate had greatly increased the oxidation of the soil. At each period the oxidation was greater in the sodium nitrate plot than in the untreated plot.

The average for the three periods was 126 for the sodium nitrate, against 100 for the check plot.

The acid phosphate increased oxidation only once, and that was in the first period. At the other two periods the oxidation was less than the untreated soil. An average of the three periods gave an oxidation of 97 for the acid phosphate plot, against 100 for the check.

The limed soil also increased oxidation; in the first two periods the oxidation was greater than the check plot, and in the third period the check and the limed plots were the same. An average of the three periods gave 124 for the limed soil, against 100 for the check.

It is also seen that lime plus sodium nitrate increased oxidation greater than any other treatment. The average for the three periods was 137, against 100 for the check.

Lime plus acid phosphate caused less oxidation than lime alone, yet there was, on the whole, more oxidation than in the untreated soil. The oxidation of the lime and phosphate plot was less in each period than in the limed plot. Inasmuch as phosphate decreased oxidation when used alone and again when used with lime, it appears that acid phosphate hinders the oxidative power of this soil.

In previous work in this laboratory it was shown that fertilizers influenced the oxidation in Arlington soil, sodium nitrate greatly increased oxidation, and phosphate only slightly. With some other soils this was also found to be true; however, in numerous experiments made on the effect of fertilizers on the oxidative power of soils the results showed that fertilizers sometimes increased oxidation and sometimes decreased it, and that the effects of fertilizers are different in different soils (59).

The oxidizing power of plant roots is also influenced by calcium carbonate and fertilizer salts. Calcium carbonate increases the oxidative power of plants growing in distilled water and in soil extracts. Sodium nitrate also has this power. Calcium acid phosphate, however, depressed the oxidizing power of the plants in soil solutions (45). Thus the results secured on the Arlington plots are in accord with those secured in the earlier work on the oxidation of soils and on the oxidizing power of plants in soil solutions.

Interesting results were obtained with the effect of vanillin and salicylic aldehyde on the oxidizing power of the Arlington soil. The relative oxidation of these plots is given in Table XIX.

TABLE XIX.

Effect of Vanillin and Salicylic Aldehyde on Soil Oxidation in Susquehanna Silty Clay Loam.

Treatment	Unlimed soil				Limed soil			
	July 16	July 23	November 19	Relative average oxidation	July 16	July 23	November 19	Relative average oxidation
Soil unfertilized	100	100	100	100	100	100	100	100
Soil+vanillin	104	96	94	98	81	89	89	98
Soil+salicylic aldehyde	89	85	81	85	95	89	89	93
Soil+sodium nitrate	100	100	100	100	100	100	100	100
Soil+sodium nitrate+vanillin	86	72	93	84	89	100	77	89
Soil+sodium nitrate+salicylic aldehyde	95	82	93	90	100	89	87	92
Soil+acid phosphate	100	100	100	100	100	100	100	100
Soil+acid phosphate+vanillin	82	80	100	87	100	100	80	100
Soil+acid phosphate+salicylic aldehyde	100	109	112	107	105	119	157	127

In this table the soil without vanillin or salicylic aldehyde in each case is taken as 100; that is, the plots unfertilized are compared among themselves, and each group fertilized is similarly compared with its own treated check as 100.

The first half of the table gives the results on the unlimed soil and the second half the results on the limed soil. As in the preceding table, the oxidation for the three periods is given, and an average of the periods.

In the unfertilized soil vanillin reduced the oxidation slightly. In the first period there was a slight increase and in the other two periods a slight decrease. An average of the three periods showed a decrease in oxidation in the vanillin plot to 98, as compared to 100 for the check. The salicylic aldehyde decreased oxidation very much in each period. An average of the three periods gave an oxidation of 85 for the treated plot, against 100 for the check.

In the soil treated with sodium nitrate the oxidation power of the vanillin plot was much less in each period than in the sodium nitrate check. The salicylic aldehyde was also less than the check, but the oxidation was not lessened as much as in the vanillin-treated soil. It should be remembered, however, that the sodium nitrate check plot had itself increased greatly in oxidation over the untreated soil, which means that the soil in each of those plots has very good oxidation, and much better than in the corresponding plots in the no-fertilizer section. Yet the vanillin and salicylic aldehyde have their influence in checking oxidation even with this fertilization.

Considering the section treated with acid phosphate, vanillin had lessened oxidation, yet the salicylic aldehyde has slightly increased this function over the acid phosphate check.

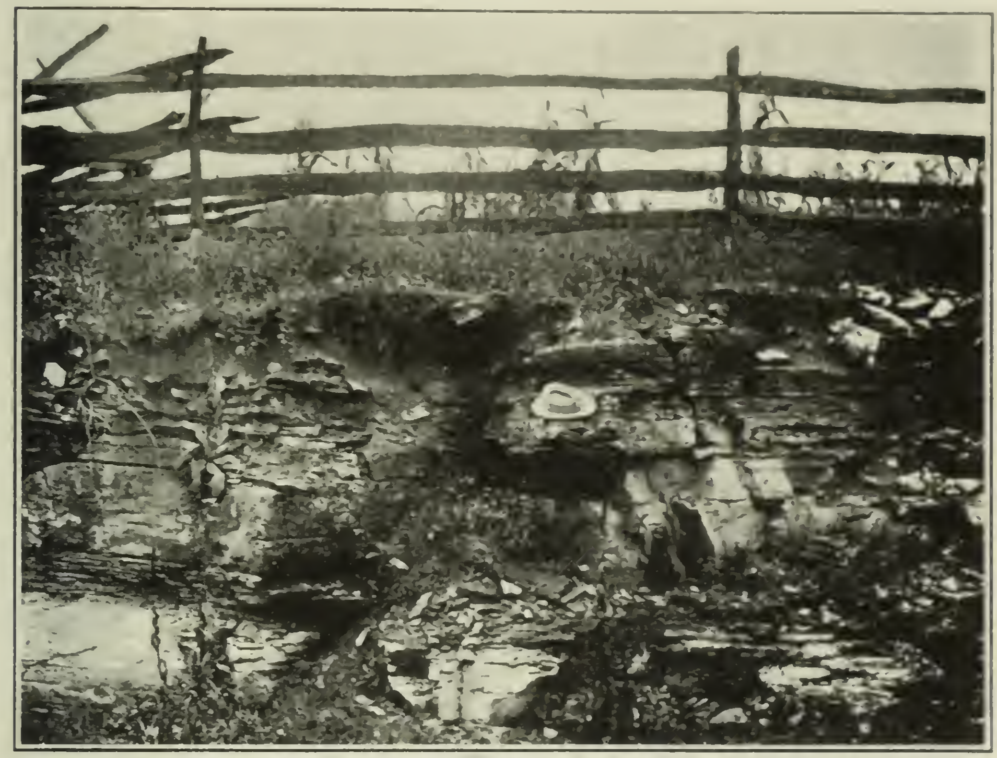
In the limed soil the compounds have also decreased the oxidizing power of the soil, except plots to which acid phosphate was added. Where lime and phosphate were used together the oxidation in the vanillin plot was the same as in its check, and in the salicylic aldehyde plot the oxidation was increased from 100 for the check to 127. It should also be borne in mind that the limed check plots had a very good oxidizing power, which was greater than in the unlimed, unfertilized soil, which means that each of the plots on the limed soil had a greater oxidizing power than the corresponding plot on the unlimed soil. However, the oxidizing power of the soil was decreased by applying vanillin and salicylic aldehyde, except where acid phosphate was used. This action of acid phosphate in combating the effects of salicylic aldehyde, and of vanillin to some extent, is rather surprising. In the former work, and also in the plots in this experiment, where no aldehydes were used, the acid phosphate did not have an appreciable influence in stimulating oxidation processes in the soil. However, this increased oxidation is in harmony with the increased crop yields and with the effect of phosphate in lessening the harmfulness of salicylic aldehyde to plant growth.

The Effect of Aldehydes With and Without Fertilizers on Hagerstown Loam.

The test of the two aldehydes was made on the Hagerstown loam (32) on the Pennsylvania Experiment Station Farm at State College, Pa., in 1914 and 1915. The plan of the experiment is given in Fig. 59, and is the same as was used at Arlington. The size of the plots differed, however. The plots at State College were 10 feet square, one four-hundred-and-thirty-fifth of an acre. Early Buff variety of cowpeas, the same as used at Arlington, was grown.

The field in which the experiment was made is in a good state of fertility. In 1913 the field grew corn and produced a good crop. It was manured with stable manure at the rate of 12 tons per acre. The soil produces good crops of wheat, grass, clover, corn, and soy beans.

FIG. 64.



Limestone rock from which the Hagerstown soils are derived: showing the formation of the Hagerstown loam soil of Pennsylvania from limestone rock—a soil in which aldehydes do not persist.

The surface soil of the experiment plots consists of about 10 inches of brown to yellowish-brown loam. It is underlaid from 10 to 20 inches by a yellowish-brown, heavy silty loam which grades to a heavy red clay within three feet. The soil is loose and friable, and is very easily worked. The drainage is excellent. The Hagerstown loam of this area is formed from disintegrated dolomite, and is recognized as among the best soils of the country and by far the most productive soil of Center County (Fig. 64).

The soil in the experiment plots contains considerable organic matter, fully as much as the soils of this type in this area. A laboratory test showed the soil to be only slightly acid. The ground selected for the plots is 72 feet by 44 feet, the plan of which is given in Fig. 59. Each plot is separated by a two-foot path. There is a very slight but uniform slope from the north plots; that is, the no-fertilizer group of plots. The soil of this piece of ground is fairly uniform. The vanillin plot and check B plot of the acid phosphate section on the limed soil are the lowest plots of the entire series; the slope is toward them, and they are somewhat darker and richer in organic matter.

The Results Obtained.

The general details of the experiment as to the application of the aldehydes, fertilizers, etc., are the same as those described in the Arlington test. In 1914, the first year's test, the cowpeas were planted May 27, five rows to each plot; unfortunately the season was very dry during May and June, and as a result of this a very poor stand was secured. The experiment was unsatisfactory in that a uniform stand was lacking, and it was unsafe to draw any conclusion from the results. However, there were very little differences in the growth on the differently treated plots. The weights of the vanillin plot show a reduction of six per cent. in dry weight of hay. The yield of cured hay on the salicylic aldehyde plot was practically the same as on the check plots. The indications show that the vanillin and salicylic aldehyde have very little effect on this soil.

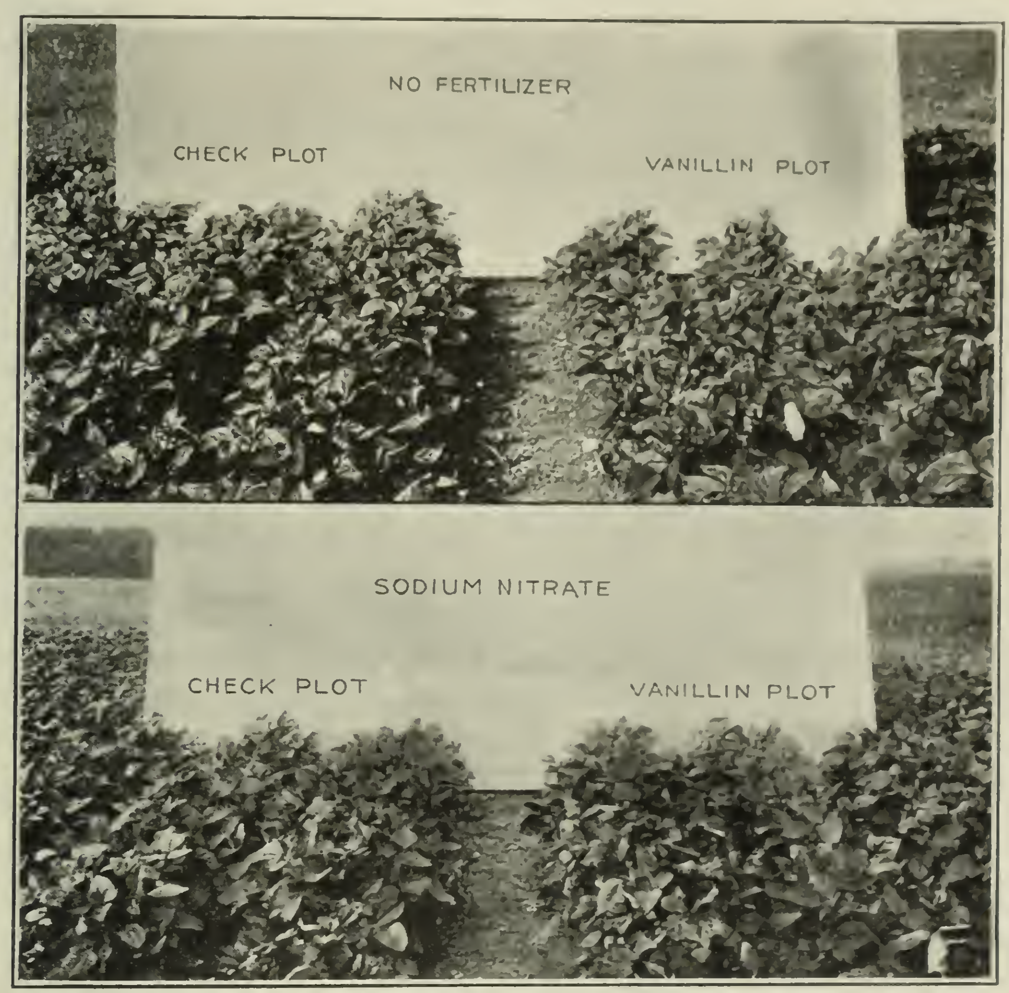
The experiment was conducted the second year, 1915, on the identical plots used in the first test, and the results secured are more satisfactory and conclusive. The peas germinated well and a uniform stand was secured. When the plants were two to three inches high the growth on the vanillin and salicylic aldehyde plots of the unfertilized section appeared to be slightly behind the plants on the other plots.

On July 19 the plots were showing some differences in growth. On the unlimed soil the two checks in the no-fertilizer section had made about equal growth. The plants on the vanillin plot had made less growth than the checks. They appear about 20 per cent. smaller. They are not as tall nor have they broadened out as much as the checks.

On the salicylic aldehyde plot the growth is much better than the vanillin plot, but it is not as good as the check plots. There seems to be a difference of about 10 per cent. in growth.

On the fertilized soil the growth on the differently treated plots is more uniform; the plants on the vanillin and salicylic aldehyde plots are somewhat smaller than the checks. The growth, on the whole, is good on all the plots; the plants are strong, healthy, and thrifty.

Fig. 65.



Effect of vanillin on cowpeas on Hagerstown loam at the Pennsylvania Experiment Station (1915).

On September 9 photographs were taken of some of the plots, and these are shown in Fig. 65. At this time the vanillin and salicylic aldehyde plots of the no-fertilizer section on the unlimed soil were smaller than their checks. This was especially true of the vanillin plot. On the sodium nitrate section the growth on the vanillin plot was almost as good as the respective check.

The crop was cut and weighed September 13. The plants had made their full growth, but were still green and full of blooms. The weight of the entire plant was taken; no attempt was made to pick the peas, as they were immature.

After the green weight was taken the vines were spread upon the plots and allowed to become dry. The weight of the cured hay was taken September 15, and the yields are given, together with the green weights, in Table XX.

As seen in the table, the two check plots in the no-fertilizer section of the unlimed soil produced approximately the same yield. The vanillin reduced the green weight yield from 100 as an average of the two checks to 84, a reduction of 16 per cent. In dry weight there was also a 16 per cent. decrease. The salicylic aldehyde reduced growth in green weight from 100 to 88, a reduction of 12 per cent., and in dry weight from 100 to 87, or 13 per cent.

On the sodium nitrate soil the aldehyde had less harmful effects. The vanillin reduced the yield only three per cent. in green weight, and in dry weight there was an increase of two per cent. As the crop grew it was apparent that the growth on the vanillin plot was as good as the checks. The foliage and the number of runners were about the same on both plots. This action of nitrate in overcoming the harmfulness of vanillin is in harmony with the result secured in the Arlington soil. The growth on the salicylic aldehyde plot was not altogether as good as the checks. The foliage was not so dense and there were fewer runners. In the table it is seen the green weight was reduced from 100 to 90, a reduction of 10 per cent., and in dry weight there was a reduction of 9 per cent.

In the acid phosphate section the growth on the vanillin plot was somewhat smaller than on the checks; considering the green weight, growth was reduced from 100 to 91, a reduction of 9 per cent., and in dry weight a reduction of 13 per cent. On the salicylic aldehyde plot the growth was as good as on the checks. This was apparent before the crop was cut. The density of the foliage and the number of runners was about the same on both plots. The behavior of phosphate in ameliorating the effects of salicylic aldehyde is also in harmony with the Arlington results.

On the unfertilized section of the limed soil neither vanillin nor salicylic aldehyde had very much effect. In green weight there was a reduction of 9 per cent. in the vanillin plot and 8 per cent. in the salicylic aldehyde plot. The reduction in dry weight was 15 per cent. for vanillin and 7 per cent. for salicylic aldehyde.

TABLE XX.

Effect of Vanillin and Salicylic Aldehyde on the Growth of Cowpeas on Hagerstown Loam at State College, Pa., and the Effect of Fertilizers and Lime. (Results Given in Pounds Per Plot.)

Treatment	Unlimed soil				Limed soil			
	Green weight		Dry weight		Green weight		Dry weight	
	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight	Pounds	Relative weight
No-fertilizer section:								
Check A	59.00	100	21.75	100	62.50	100	23.50	100
Check B	60.25		22.50		61.00		23.50	
Vanillin	50.00	84	18.50	84	56.00	91	20.00	85
Salicylic aldehyde	53.50	88	19.25	87	57.00	92	21.75	93
Sodium nitrate section:								
Check A	63.00	100	23.25	100	58.00	100	21.00	100
Check B	60.00		22.75		55.50		21.25	
Vanillin	59.50	97	23.50	102	55.00	97	21.50	102
Salicylic aldehyde	55.50	90	21.00	91	55.00	97	22.50	106
Acid phosphate section:								
Check A	59.00	100	22.00	100	62.00	100	24.25	100
Check B	61.00		24.50		67.00		28.25	
Vanillin	54.50	91	20.25	87	67.00	104	*26.75	102
Salicylic aldehyde	61.50	103	23.25	100	61.00	95	*23.25	89

* See discussion in the text.

On the limed soil fertilized with sodium nitrate or acid phosphate neither aldehyde had any appreciable harmful effect.

A close examination of the table shows that the yields of the duplicate check plots are very close together, except in the acid phosphate section of the limed soil. Check A produced only 62 pounds green matter and 24¼ pounds dry hay, while Check B produced 67 pounds green matter and 28¼ pounds dry hay. This difference was apparent during the growing season. On close examination of the soil of the two plots it was found that the surface soil in Check B was several inches deeper and had more organic matter. This was also true of the adjoining vanillin plot. The lay of the ground is such as to make it possible for Check B plot and the vanillin plot to get the drainage from several of the surrounding plots. Under the circumstances, in this section it would be better to compare the vanillin plot with Check B, and the salicylic aldehyde plot with Check A. By making this comparison it is seen the yield in the vanillin plot is as good as in Check B, and the yield in the salicylic aldehyde plot is almost the same as in Check A.

In the unlimed soil with no fertilizers both the vanillin and salicylic aldehyde had a depressing effect on crop growth, but this was not very marked. When the soil was fertilized with sodium nitrate the harmfulness of both compounds was lessened. This was especially so with vanillin, where practically no depression in growth was observed. Acid phosphate also ameliorated the effects of both compounds. In this case salicylic aldehyde had no depressing effects.

On limed soil the effects were noticeable, but their harmfulness was not as much as on the unlimed soil. There were no effects from the aldehydes on the limed soil fertilized with sodium nitrate or acid phosphate.

Examination of the Soil for Aldehydes at the End of the Growing Season.

The soils were examined to determine if the added vanillin and salicylic aldehyde were still present in the soil at the end of the growing period. Twenty pounds of soil were taken from each plot and subjected to the process for the isolation of aldehydes. In 1914 the test showed the presence of aldehydes in only one plot. This was the plot to which salicylic aldehyde had been added on the sodium nitrate section of the unlimed soils. The extracted material from this soil gave the color reactions for aldehydes. This material, when dissolved in distilled water, was harmful to wheat seedlings, reducing growth about 30 per cent.

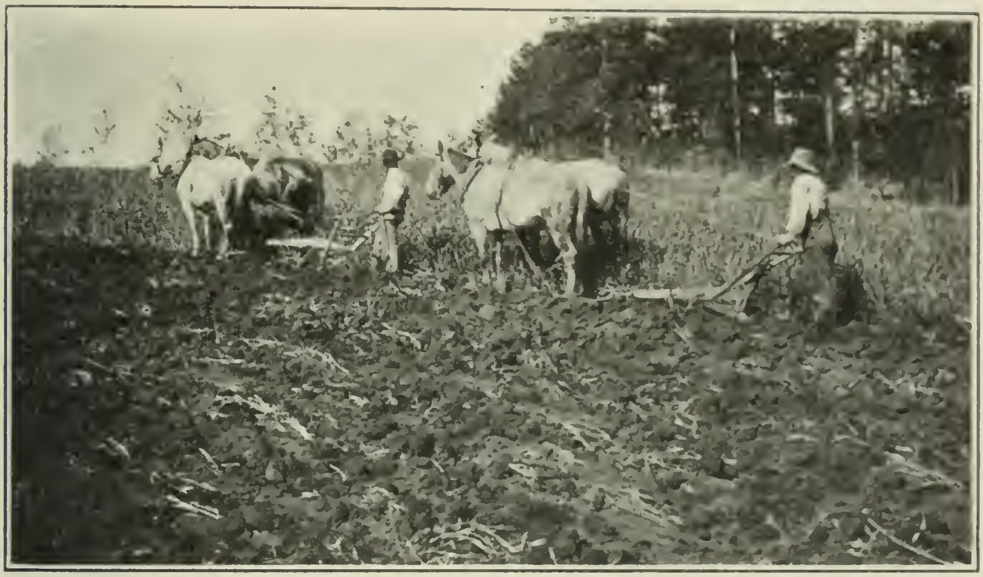
Notes taken in September showed that the growth on this plot was the poorest in the series, yet at the end of the season this was not especially noticeable.

No reason can be assigned why the aldehyde should persist in this particular plot, while in every other case it was not found to be present.

After the growing season of 1915 no aldehydes could be isolated from any of the plots. Such harmful effects as were observed were probably due to the influence of the added materials at the time and shortly after its application. There were three applications, the first on July 10, when the seeds were planted, and the last on July 19, when the plants had made considerable growth. If the aldehydes had remained in the soil as such throughout the growing season, the crops would undoubtedly have shown their effects to a much greater extent.

It is rather significant that in the Hagerstown soil, which is a strong productive soil with strong oxidizing power, the aldehydes, when added, did not stay as such, but were destroyed or changed, while in the Arlington soil, which is an unproductive one, with low oxidizing power, the added aldehydes persisted for months and remained as such throughout the growing season, to have its effect on the crop (Fig. 66).

FIG. 66.



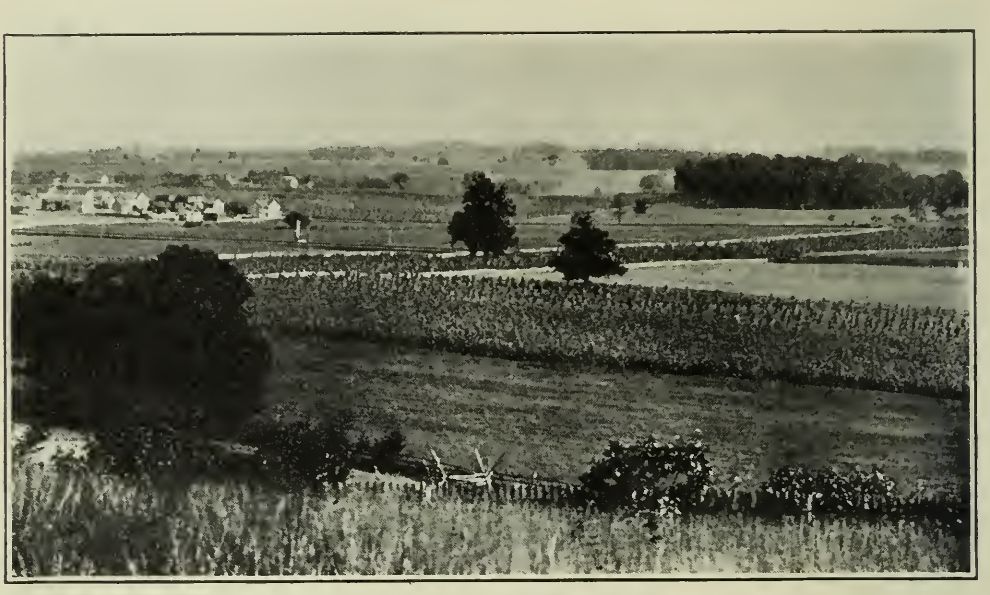
Turning under green crops to enrich the soil in organic matter. Soil management practised on the Hagerstown loam which induces thorough aeration and oxidation.

The nature of this Hagerstown soil seems to be such that organic compounds of the kind added cannot exist for any length of time. Nor could harmful compounds of this nature be formed or remain in this soil. It has been pointed out that the Hagerstown soil has a strong oxidizing power and is otherwise a fertile productive soil. These added aldehydes are undoubtedly acted on in the soil and destroyed or changed to other compounds that are not harmful (Fig. 67).

The contrast between the action of aldehydes in the Arlington soil and in the Hagerstown loam is interesting and demonstrates that such materials can exist in one soil and have their effect on growth, while in another soil they are destroyed by oxidation or other biological processes of the soil and do not remain for a sufficient length of time to have appreciable influence.

The establishment of the fact that added aldehydes may remain in some soils and disappear in others may explain the reason that in the pot tests with different soils the growth in some was affected by aldehydes and in others it was not. In experiments with the effect of organic compounds in soils, the fact as to whether or not the added material remains as such throughout the growing period should always be demonstrated. To draw conclusions as to the physiological effect of a certain compound without the knowledge of its stability under the conditions of the experiment may lead to erroneous conclusions. Upson and Powel (76) and Funchess (21) were probably working with soils in which the organic substances under study were destroyed, yet they conclude that these materials were not harmful. Davidson's (16) work with cumarin and vanillin would also have been much more valuable if he had examined his soils to establish whether or not the aldehydes remain in the soil.

FIG. 67.



Showing excellent crops growing on the Hagerstown loam of Pennsylvania, a soil which destroys aldehyde by active oxidative activities.

(To be concluded.)

A PHYSICAL STUDY OF THE WELSBACH MANTLE.*†

BY

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VIII. MANTLES COMPOSED OF OXIDES AND MIXTURES OF OXIDES OF HIGH EMISSIVE POWER IN THE VISIBLE SPECTRUM.

1. Thoria-Ceria.

The series of mixtures of thoria and ceria, in which is included the Welsbach mantle of commerce, is in many respects the most interesting of the mixtures studied. In it are exhibited in striking manner the characteristics of an optimum proportion of the constituents, a fundamental difference in the optical properties of the hot and cold mantle, and a greatly different behavior under different kinds of heating. A full discussion of this series therefore covers many of the characteristics found in others, which can, in their turn, be described briefly in terms of their likeness or unlikeness to the thoria-ceria mixtures.

Gross Physical Characteristics.

Pure thorium oxide, ThO_2, is white, of high reflecting power (85 per cent.), and does not show any color change on heating in a quartz tube in the Bunsen flame. Pure cerium oxide (CeO_2) is either white or brownish white, depending on the method of preparation. Both varieties turn deep yellow or brown in heating to a few hundred degrees, a characteristic which persists in the mixtures of ceria with thoria to very low percentages of the former. It is exhibited clearly in the regular commercial mantle (approximately 1 per cent. ceria) when this is turned low.

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* Based on a lecture delivered by Doctor Ives at a meeting of the Section of Physics and Chemistry held Thursday, January 10, 1918. Contributed by the Research Laboratories of the Welsbach Company, Gloucester City, New Jersey.

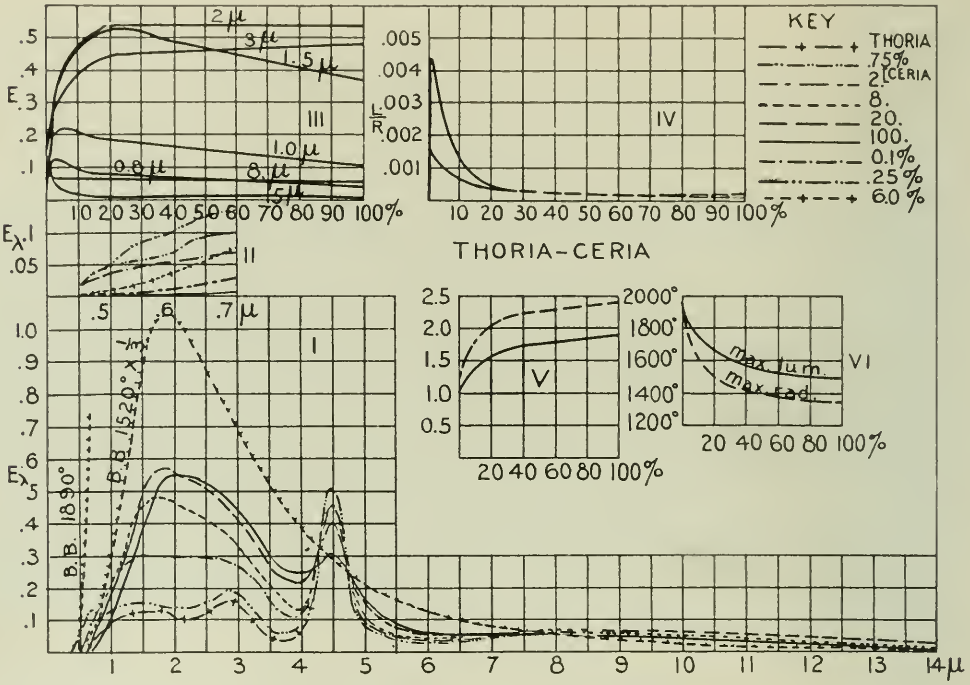
† Concluded from page 438, Vol. 186, October, 1918.

The mantles for study were made of silk. The pure thoria mantles had a weight of 0.009 gramme per cm.^{2}, the pure ceria of 0.0097 gramme per cm.^{2}

Temperature.

The relationship between constitution and temperature is shown in Fig. 16 (VI) for these mixtures. A point of importance appears at once from these curves, namely, the possibility of two adjustments: (1) The adjustment which would be made from the standpoint of light-production—that is, the adjustment of maximum luminosity; and (2) that which would be made if one wished the maximum of radiant heat. The first adjustment is with the flame just inside the mantle; the second is with the flame coming through and enveloping it. In the pure ceria mantle the difference is most striking. As the flame is turned up the mantle gains in brightness until a certain point, when, as the flame strikes through, the light drops off as though quenched by a suffocating gas. This happens first at the top of the mantle,

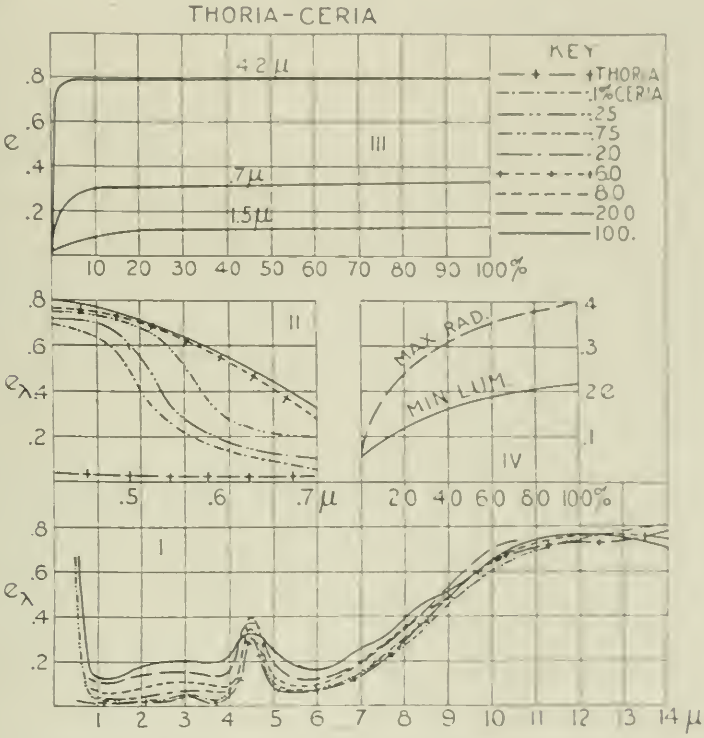
Fig. 16.



Properties of thoria-ceria mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission constitution relation, isochromatics.
IV. Radiant luminous efficiency—constitution relation.
V. Radiance—constitution relation.
VI. Temperature—constitution relation.

leaving a bright ring in the bottom, and then with a still larger flame the whole mantle goes dull. As is shown by the curves, and in accordance with the temperature radiation relationship discussed above, the temperature is much lower for the condition of maximum radiation. This different behavior does not appear in the pure thoria mantle, but is a characteristic of the ceria constituent, and will be discussed in greater detail later. The temperature range between the pure thoria and the pure ceria is

Fig. 17.



Emissive power characteristics of thoria-ceria mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution—emissive-power isochromatics.
IV. Total emissive power—constitution relations.

about 400° (1930°–1500°) for the condition of maximum luminosity, and about 600° (1930°–1340°) for maximum radiation. The fall in temperature is most rapid for the low percentages of ceria.

Total Radiation and Emissive Power.

The variation in total radiation with constitution is shown in Fig. 16 (V) for both adjustments, and in Fig. 17 (IV) is given the variation in emissive power.

The radiant emission of the pure ceria mantle is nearly twice that of the pure thoria for the condition of maximum luminosity, and more than twice for maximum radiation. As with the temperature changes, the increase in emission is much more rapid for the smaller admixtures of ceria than later.

The emissive power of thoria, as previously noted, is exceedingly low, about 4 per cent. For the adjustment of maximum luminosity the rise of emissive power is rather gradual, up to 22 per cent. for pure ceria. For maximum radiation it is more rapid for the smaller percentages of ceria, reaching a maximum value of 40 per cent.

Both the behavior of the emission and the emissive power will be analyzed in the discussion of the spectral distribution curves. It is to be noted, as a general criticism of all the emissive power data, both the total and the spectral distribution, that the widely different temperatures and radiating characteristics with various adjustments make the figures given subject to very large possible errors, and the values shown for plotting are not in every case as entirely consistent with each other as could be desired.

Radiant Luminous Efficiency.

In Fig. 16 (IV) is shown the variation of radiant luminous efficiency with constitution. The general characteristic of mixtures of low and high visible emissive powers is shown; namely, the optimum for a certain low percentage of the blacker substance. In this case this maximum efficiency (0.0043) for the whole mantle is over three times that of a black body at the same temperature, the latter being shown by the lower line of the diagram, and occurs for a very small percentage of ceria (0.75 per cent.) and a high temperature (1900°). (For the brightest part of the mantle, through the 1 cm. diameter aperture, the efficiency is about 0.009.) This advantage over the black body persists through all the mixtures, although the difficulty of measuring the very low efficiencies of the ones rich in ceria, and the uncertainty in the corresponding temperatures, prevent a reliable quantitative estimate of the extent of the advantage in their case.

This curve of radiant luminous efficiency merely exhibits the well-known candle-power-ceria content relationship, giving no explanation of the very high value of efficiency attained. The reason for the exceedingly high value is given by the analysis represented in the spectral distribution curves.

Spectral Distribution of Emission and Emissive Power.

The spectral distribution of radiant emission is shown both for the visible and the infra-red regions in Fig. 16 (I and II), while Fig. 16 (III) exhibits the isochromatics or variations of the emission for selected individual wave-lengths.

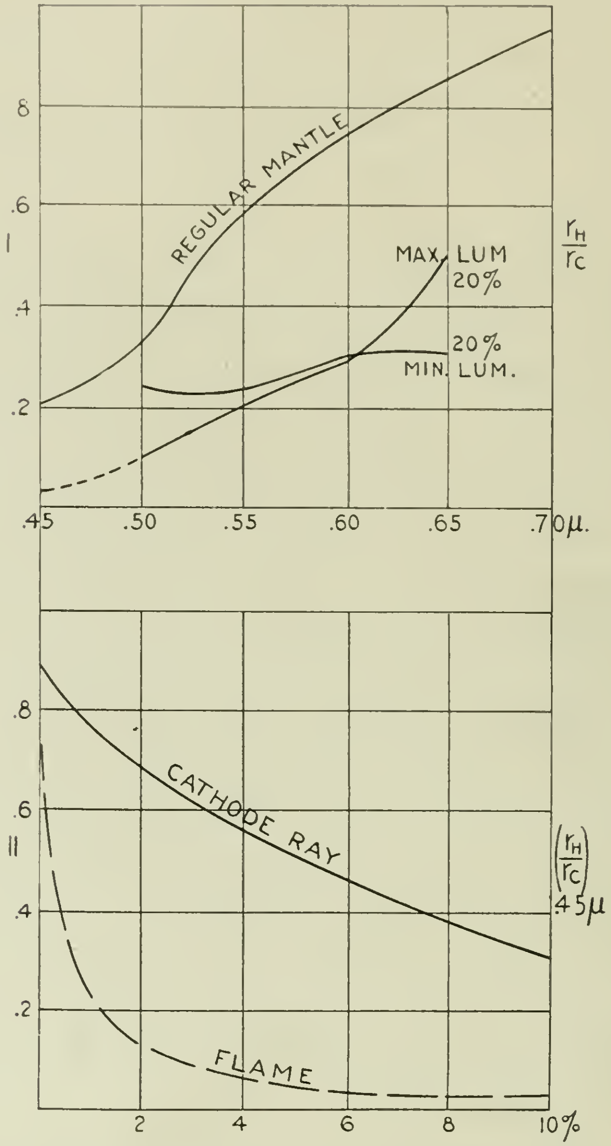
The significant feature of these emission curves is the practically uniform and continuous increase of emission with ceria content in the infra-red region, and its initial very rapid rise to a maximum for 0.75 per cent. ceria and subsequent fall in the visible region. This feature is clearly presented by the isochromatics (III).

When it comes to the emissive power, the behavior is somewhat simpler. Emissive power increases at all wave-lengths with increasing ceria. In this case the significant feature is the rate of increase of emissive power with ceria content at the various wave-lengths (III). While for the infra-red wave-lengths the rise is uniform and gradual for the visible region, and particularly in the blue, the rise of emissive power is very abrupt, reaching saturation for a very low percentage. Not only this, but the actual emissive power attained is very high. As pointed out by Rubens, the ordinary mantle, with its approximately one per cent. of ceria, is practically black for the blue end of the spectrum. This blackness is identical with the yellow coloration on heating, which has already been mentioned. When hot, as shown by the emissive power curves, the ordinary mantle, which is white when cold, becomes deep brown in color. This coloration is due to the occurrence in the hot ceria of an absorption band whose long wave end is comparatively abrupt, and which is almost completely developed with only a small amount of ceria present. This is shown in another way by the ratio of hot to cold reflecting power through the spectrum for a 1 per cent. ceria mantle, Fig. 18 (I). Since the cold mantle is practically white, the hot mantle is thus shown to be strongly yellow.

On the addition of more ceria beyond one per cent., the absorption extends somewhat toward the infra-red, in which region a general absorption also develops. Due to this increased absorbing (emitting) power, the emission increases and the temperature falls. This fall of temperature is at once reflected in the lower emission for the short visible wave-lengths, with the resultant fall in luminosity.

The actual values attained by the emissive powers are, for the most luminous condition, less than 50 per cent., even with pure ceria, except for the visible region, and the very long wave infra-red beyond 9μ, where saturation is again approached. There is thus a region of low emissive power centering around 4μ which, as will be seen, occurs in most of the oxides.

Fig. 18.



Relationship between hot and cold reflecting power in thoria-ceria mixtures:
I. Behavior in different parts of spectrum.
II. Behavior of various mixture proportions in the flame and under cathode-ray bombardment.

Behavior in Different Parts of the Flame.

The fact that ceria has a different emissive power in the oxidizing and reducing flame was noted by Féry[8] in 1903, and he built largely upon this fact a theory that the efficiency of the mantle is to be explained by the highly emitting ceria in a reducing condition, imbedded in thoria, which is poorly emitting in the same condition. This theory is inadequate, for it does not take into account the different spectral distribution of emissive power of the two constituents, which is really the dominating factor, and, moreover, in the ordinary mantle burner the flame is *oxidizing* on the outside, not reducing. It is only when the flame is made so full as to envelop the mantle that the latter is subject to reducing conditions.

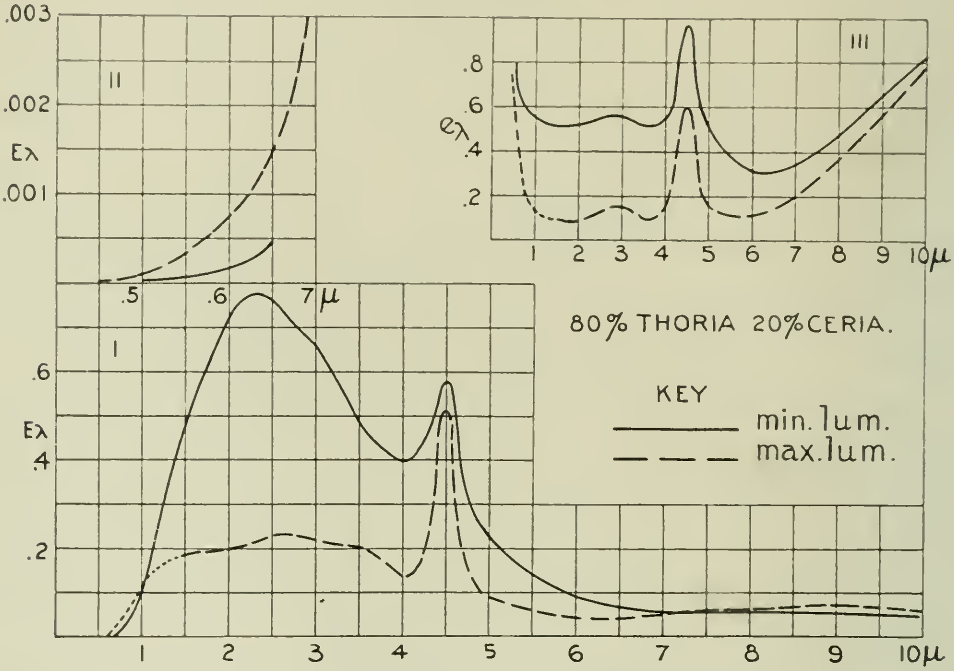
With a view to determining more specifically the change in character occurring in going from one type of flame to another, a supplementary set of spectral emission curves was made, and also some experiments on fragments of mantle heated in the interior of the flame and cooled in a reducing atmosphere.

The emission curves were made on a mantle of 80 per cent. thoria and 20 per cent. ceria composition, which exhibited the characteristic behavior excellently. Extreme conditions of the flame were taken so that the results do not form part of the same series as the curves already shown. The oxidizing and reducing flame emission curves are shown in Fig. 19 (I and II), and the corresponding emissive power distributions in Fig. 21 (III), while in Fig. 18 (I) are exhibited the changes of reflecting power in the visible region for the two kinds of heating. It is evident from these curves that not only is the emissive power in the reducing flame much higher, but it is less selective. The mantle approximates *gray* rather than brown, as is well shown by the hot and cold reflecting powers, where the very great drop in reflecting power in the blue, which is characteristic of ceria in the ordinary mantle, is greatly decreased.

This conclusion is supported by the experiments on heating a fragment of the mantle in the inner part of a Meker burner flame, which is practically free from oxygen (less than 0.1 per cent.), and removing the fragment through a quartz tube inserted in the flame, so that it cools in the products of combustion. The fragment thus treated comes out *dark gray*. Furthermore, if it is heated in hydrogen it turns *black*. In either case, upon heating in the oxidizing flame the mantle material at once reassumes its ordinary color.

The various changes gone through by ceria on heating are probably to be ascribed to the formation of several different oxides, for whose existence there is other evidence. The ordinary is CeO_2, the yellow formed on heating in the oxidizing flame is perhaps CeO_3, the gray or blue [9] formed in the reducing flame Ce_4O_7.

Fig. 19.



Characteristics of mixtures rich in ceria in oxidizing and reducing flames:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Spectral distribution of emissive power.

Behavior in the Cathode Discharge Tube.

A question long outstanding has been why the Welsbach mantle, and the materials composing it, behave altogether differently when heated in the flame and when heated by the bombardment of cathode rays. Campbell-Swinton,[10] in 1899, performed the experiment of heating a composite "mantle" composed of sectors of pure thoria, pure ceria, and the Welsbach mixture in a cathode-ray tube. He found two striking differences between the behavior of the mantles there and in the flame. First, the 99 per cent. thoria and 1 per cent. ceria mixture gave no more light than the pure thoria. Second, while the pure thoria gave a vivid incandescence, the pure ceria gave scarcely any light; in the flame the light given by pure thoria and pure ceria is not greatly different in intensity, although very different in color.

In order to repeat this experiment, use was made of the cathode-discharge tube already described, Fig. 2, and some four-part disk mantles of the design shown in the same figure, one of the sectors being pure thoria, one pure ceria, one 99 per cent. thoria and 1 per cent. ceria, and the fourth, 90 per cent. thoria and 10 per cent. ceria. On subjecting these to the cathode discharge the behavior described by Swinton was observed, the luminosity being greatest for the thoria, which gave a brilliant light, and decreasing according to the amount of ceria, the pure ceria giving only a dull glow. After continued bombardment the pure thoria sector was apparently unchanged, while those containing ceria became darkened to a bluish-gray. On heating in air this darkening disappeared, restoring the mantle to its original appearance. This darkening is thus ascribable to the well-known reducing action of the cathode discharge.

It was suspected that the failure of a small admixture of ceria to enhance the luminosity of the thoria was due to the failure to develop the strong visible absorption band, to which, as has been pointed out, is chiefly due the efficiency of the flame-heated mantle. In order to test this hypothesis a series of measurements were made of the ratio of hot to cold reflecting power for blue light (0.45 μ), both in the cathode discharge and in the flame. The results are shown in Fig. 18 (II). It is evident at once that the great increase of absorbing power conferred by the small addition of ceria to the thoria in the flame, is largely inhibited in the cathode discharge. Whereas, the blue reflecting power for one per cent. of ceria drops to 20 per cent. of its cold value on flame heating, it only falls off a matter of ten per cent. in the discharge tube. At the same time, as was shown by the experiments on heating in the reducing flame, a reducing condition increases the general emissive power of ceria, so that the effect of ceria in reducing the mantle temperature is favored in the discharge tube. The net result of thus inhibiting the selective absorption in the blue and increasing the general absorption is to quite destroy the merits of ceria as a coloring agent for thoria. More than that, while the ceria is in its most completely radiating condition when it assumes the lowest temperature, thoria, which, according to the work of Féry, has its lowest emissive power in the reducing flame, is probably also assuming a relatively higher temperature in the cathode discharge, whereby its luminosity is enhanced. Consequently the approximate equality of the ceria and thoria mantles in the oxidizing flame is no longer present in the cathode discharge. This behavior is not the complete explanation of this great difference in luminosity, which will be more fully treated when the question of convection and conduction losses is taken up.

Behavior in a Vacuum and in a Hydrogen-chlorine Flame.

Realization of the importance of the oxidizing condition led to trials of the effect of heating the mantle in the entire absence of oxygen. First the experiment was tried of heating ceria in a quartz tube which was connected with a pump and maintained at a high vacuum. It was thought that under these conditions the ceria might not show the characteristic yellowing. The experiment showed, however, that the usual yellowing took place.

Next a special mantle was made up divided vertically into two parts, one pure thoria, the other the regular mantle mixture. This was heated by a hydrogen flame burning in air under a bell jar, from which the air was then displaced by chlorine gas. A similar experiment was performed by Killing[11] to test the alternate oxidation and reduction theory of Auer, but his object was merely to determine whether the mantle became incandescent and not whether the coloring action of ceria was present. Our experiment showed clearly that the relative brilliancy of the thoria and thoria-ceria mixtures was little, if any, affected by the change from air to chlorine.

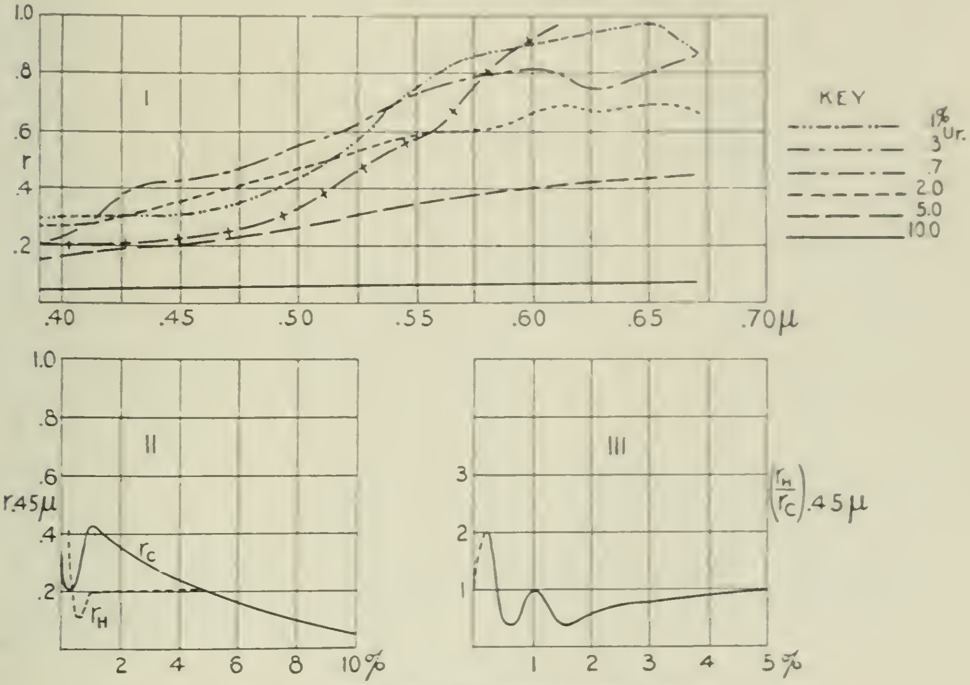
It appears from these two experiments that mere absence of oxygen is not sufficient to prevent the ceria from turning yellow and so coloring the mantle. An actual actively reducing condition, such as the cathode discharge tube, is essential. Even the reducing region of the Bunsen burner, although it causes the large drop in temperature and luminosity already noted in pure ceria, does not noticeably affect detrimentally the behavior of the regular mantle mixture. It thus appears that the absorption band in the blue region and the general absorption through the infra-red behave as though due to separate mechanisms. The latter is rather easily increased by a non-oxidizing condition; the former is only inhibited by a very strongly reducing one.

2. *Thoria-uranium Oxide.*

Physical Characteristics and Behavior in General.

Of all the mantle mixtures studied, those of uranium oxide with thoria show the nearest approach in efficiency to the regular Welsbach mantle. The approach is, however, only to about 50 per cent. of that efficiency. In some other respects, however, uranium oxide is even more interesting than ceria in its coloring action.

Fig. 20.

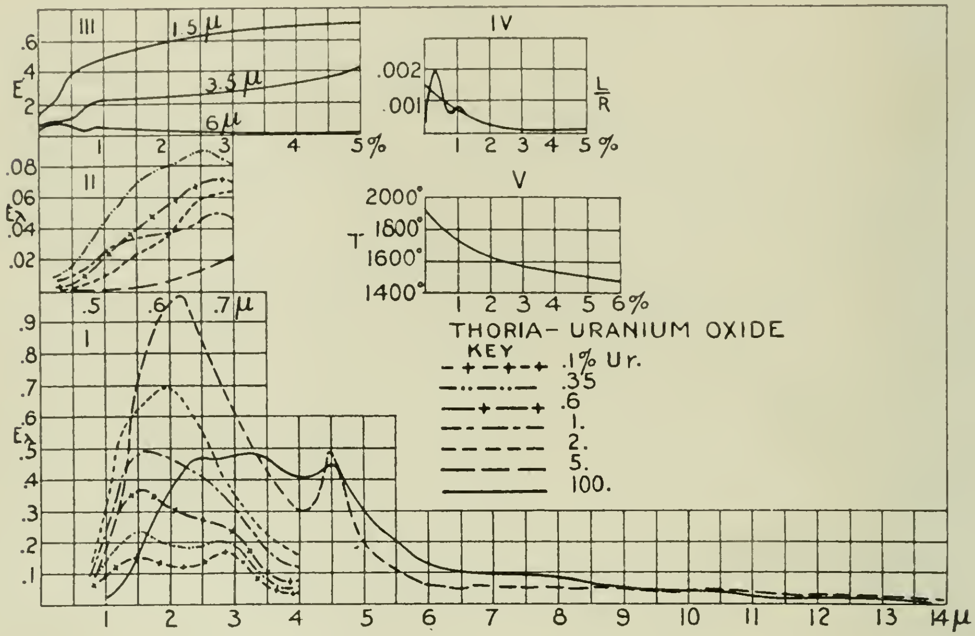


Reflecting-power characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution, visible region.
II. Reflecting-power-constitution relation for 0.45 μ.
III. Ratio of hot to cold reflecting power at 0.45 μ for mixtures from 0 to 5 per cent. uranium oxide.

Uranium oxide itself is a deep brown, nearly black substance, which cannot be made up into a well-shaped mantle. As it is mixed with thoria the mixture is progressively lighter brown in color, until at about 7 per cent. uranium oxide, where it is nearly white, the mixture starts to assume a lemon-yellow color, which is at a maximum near 0.35 per cent., after which the yellow becomes paler until the white of pure thoria is reached. This series of changes is shown in the spectral reflecting power curves of Fig. 20 (I) and more clearly in the isochromatic reflecting power constitution curve of Fig. 20 (II) for 0.45 μ.

A further interesting property of this lemon-yellow coloration is found on examining the relation of hot to cold reflecting power at 0.45 μ as shown in Fig. 20 (III). On applying this ratio to the cold reflecting power isochromatic, thus obtaining approximately the hot reflecting power behavior with varying concentration, it is seen that the maximum absorption is shifted to a higher percentage of uranium oxide. Thus, while the maximum coloration cold is about 0.35 per cent., it is about 0.7 per cent. hot.

Fig. 21.



Characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission-constitution isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Temperature-constitution relation.

This absorption band has much in common with the band developed in the same region by ceria, and, like it, is responsible for the comparatively high luminous efficiency attained.

Considerable difficulty was experienced in obtaining consistent results in the visible spectrum with the uranium oxide mantles, due to the somewhat transient character of the yellow coloration. It appears either to volatilize, leaving the mantle streaked, or to be dependent on the oxidizing or reducing character of the flame at the time of extinguishing. Like the ceria coloration, it is inhibited by the reducing condition of the cathode discharge, in which the most efficient thoria-uranium oxide mixture shows no advantage over pure thoria.

Temperature and Total Radiation.

The drop in temperature produced by adding uranium oxide to thoria is much more rapid than the drop due to ceria. It is shown for the first 5 per cent. addition in Fig. 21 (V). Already for only 5 per cent. the temperature is reduced to 1500°, where with ceria in the reducing flame the corresponding drop is only to about 1700°. The total radiation is fixed approximately, in accordance with the relationship shown in Fig. 10 (I), by the temperatures.

Radiant Luminous Efficiency.

The relationship between constitution and radiant luminous efficiency shown in Fig. 21 (IV) is unique among the mantles studied in showing two maxima. The first of these occurs at about 0.35 per cent. uranium oxide, the second at about 1 per cent. They are obviously connected, as is borne out by the spectral distribution, the first with the transient yellow coloration, the second with the steadily increasing brown coloration. Due to the latter alone, this series of mixtures would be similar to the ceria mixtures and others to be treated later. The maximum efficiency (0.0008) would be only slightly over that of a black body at the same temperature. The initial yellow coloration gives an efficiency (0.002), more than half as much again as the black body at the same temperature (lower light line), and this temperature, because of the small general emission for this concentration (0.35 per cent.), is quite high.

Spectral Emission and Emissive Power Distribution.

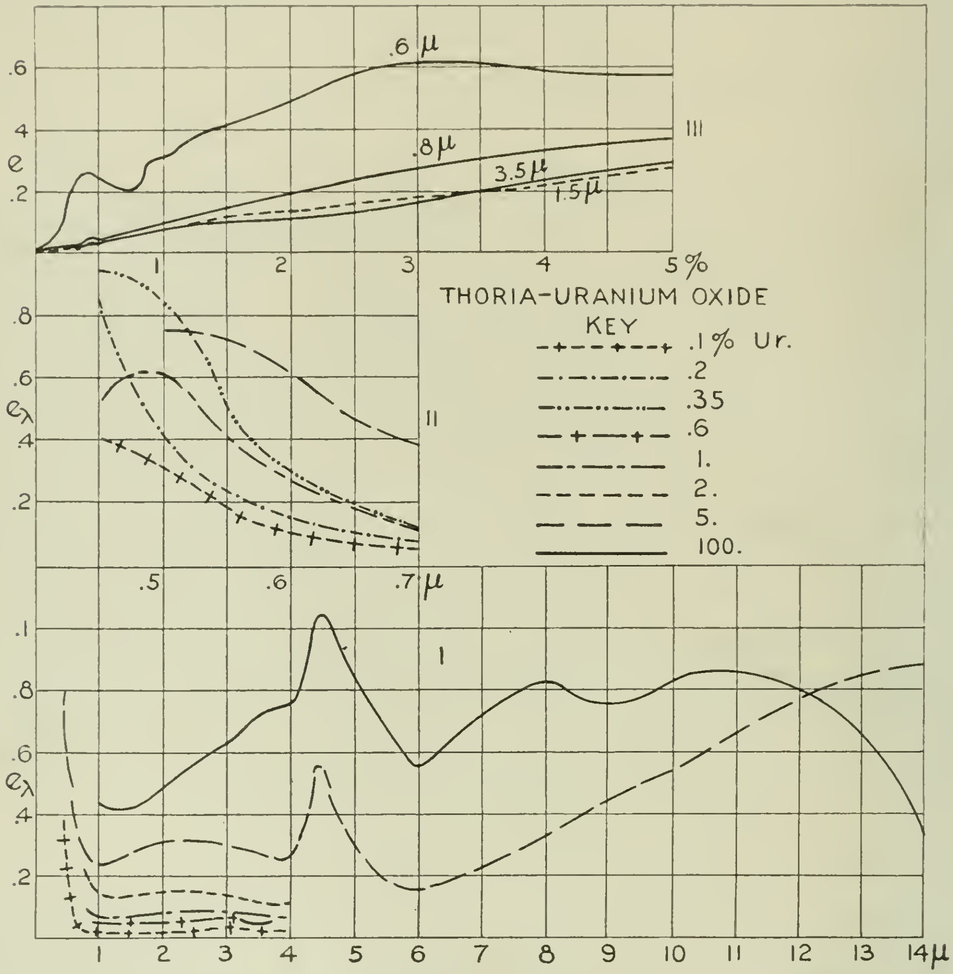
These are shown in Figs. 21 (I, II, and III) and 22 (I, II, and III), which are largely self-explanatory. The emissive power in the infra-red rises much higher than for ceria, in agreement with the temperature data, and exhibits a steady increase with concentration. In the visible region the emissive power and the emission show the characteristic maximum at 0.35–0.50 per cent., the emissive power continuing to rise after passing through the minimum at 0.8 per cent., the emission rising slightly, but then falling off because of the drop in temperature. The very irregular character of the isochromatics (III) is probably in part due to the difficulties of exact measurement introduced by volatilization, already noted.

3. *Thoria-manganese Oxide.*

Physical Characteristics and Behavior in General.

Manganese oxide behaves much as uranium would were it not for the latter's anomalous behavior in the region where it shows the lemon-yellow coloration. Manganese oxide is dark brown, nearly black in color, and its mixtures with thoria show a regular progression of color down to the white of the latter.

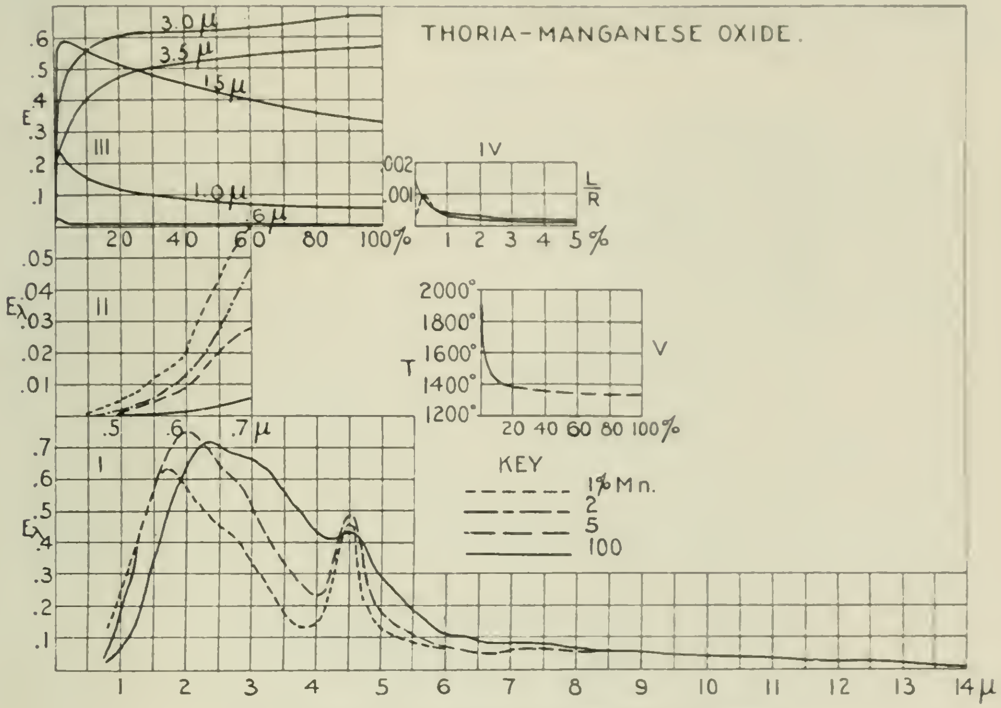
Fig. 22.



Emissive-power characteristics of thoria-uranium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Emissive-power-constitution isochromatics.

Perhaps the feature of most interest displayed by manganese is its tendency to decolorize on heating, thus being opposite in behavior to ceria, although the amount of the effect is much less. It is exhibited by the ratio of hot to cold reflecting power, which is 1.35 for wave-length 0.55 μ for 100 per cent. manganese oxide. It is also shown in a very striking manner by moving a thoria-manganese oxide mantle from the outside to the inside of the Bunsen flame. On the outer edge of the flame the mantle is dull; inside it glows brilliantly, thus being exactly opposite in behavior to ceria. The visible decolorizing is apparently produced by the oxidizing flame. It is possible, also, that a decrease of infra-red emissive power is brought about by the reducing flame.

Fig. 23.



Characteristics of thoria-manganese oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Emission-constitution isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Constitution-temperature relation.

Temperature and Efficiency Characteristics.

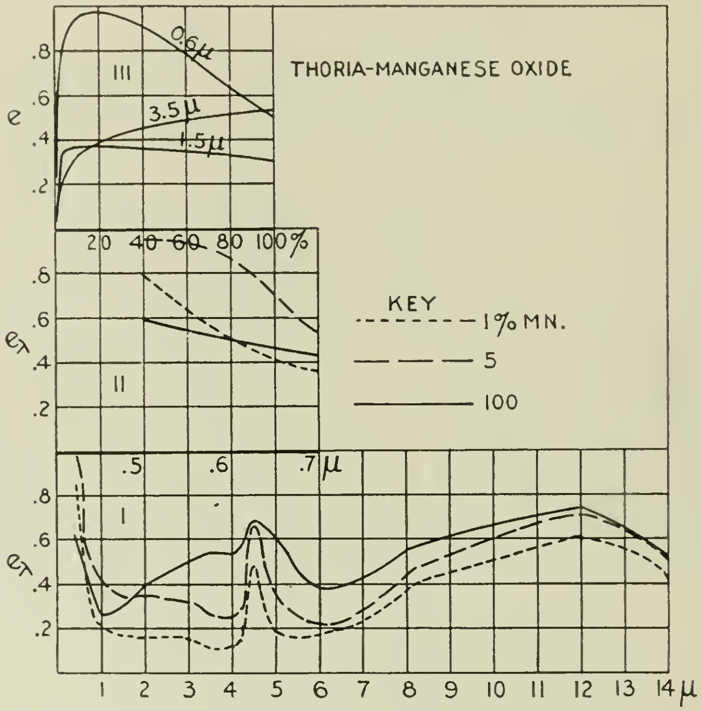
The variation of temperature with concentration, Fig. 23 (V), is of the same character as with uranium and of nearly the same magnitude.

The radiant luminous efficiency, as shown in Fig. 23 (IV), goes through the maximum characteristic of mixtures with thoria of substances of relatively high visible emissive power. The highest efficiency attained 0.0009, for 0.25 per cent. is, however, only slightly above the black body at the same temperature (light line), and, while for higher concentrations the advantage over the black body is greater, the decreased temperature reduces the efficiency to insignificant values.

Spectral Emission and Emissive Power Distribution.

These are exhibited in Fig. 24, which is self-explanatory. As in the case of uranium, a high visible emissive power, comparable to that of ceria, is of small value for light-production because of the large amount of general infra-red absorption. The isochromatics show clearly the whitening which sets in in the visble region with higher concentrations of manganese.

Fig. 24.



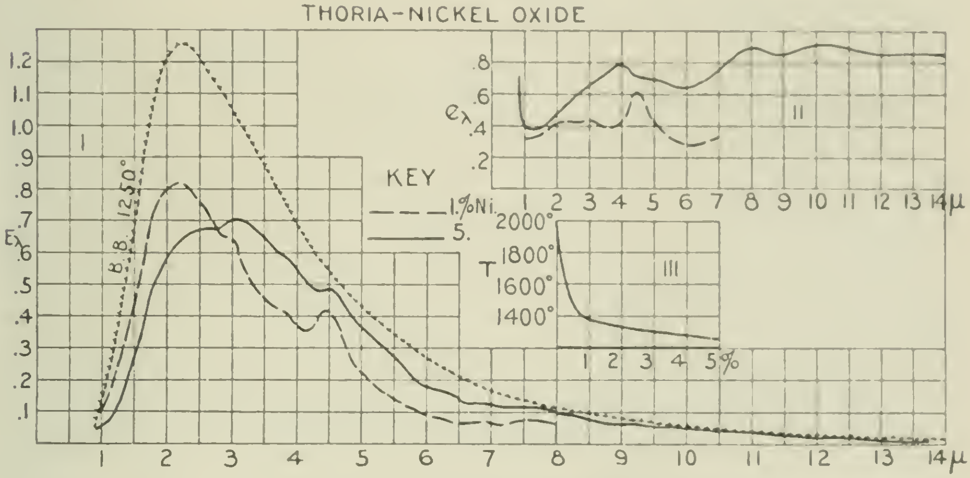
Emissive-power characteristics of thoria-manganese oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emissive-power isochromatics.

4. *Thoria-nickel Oxide.*

Nickel belongs with a group, which includes cobalt, chromium, and vanadium, upon which very little time was spent, because of the small interest from the standpoint of light-production. In each case the total emissive power is large, resulting in a rapid drop of temperature for quite low admixtures with thoria. They exhibit the characteristic increase of luminous efficiency over thoria for small admixtures, but this increase is not in any way comparable with that shown by uranium or cerium.

The spectral emission and emissive power curves for 1 per cent. and 5 per cent. nickel are shown in Fig. 25 (I and II). The corresponding temperatures are 1250° and 1360° K. (IV). Nickel oxide is, of all substances measured, the blackest, having for 5 per cent. already a higher emissive power than pure cerium or uranium oxide. The blackness of the visible region of the thoria-nickel mixture is increased by the reducing cathode-discharge bombardment.

Fig. 25.



Characteristics of thoria-nickel oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emissive power.
III. Constitution-temperature relation.

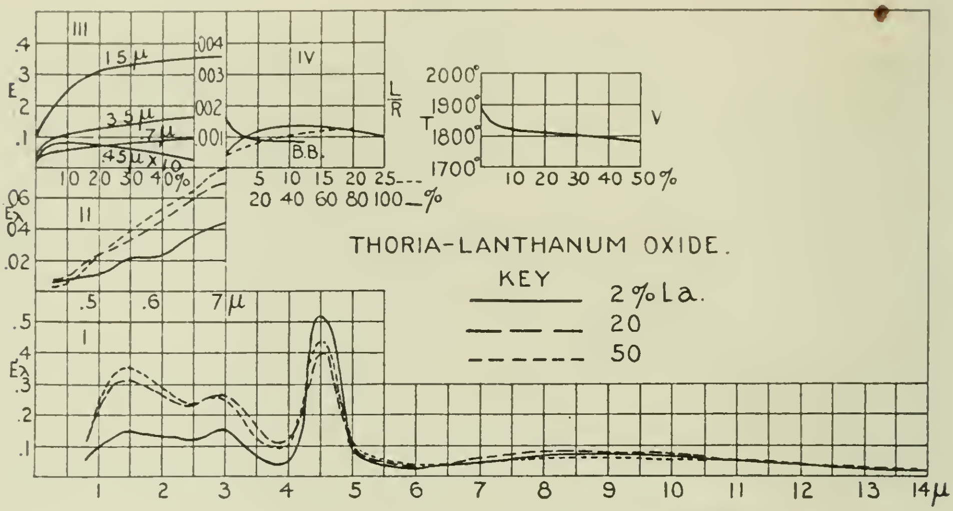
5. *Thoria-lanthanum Oxide.*

Lanthanum is of peculiar interest because, while a single oxide, it exhibits the spectral distribution of emissive power and the changes between the hot and cold states characteristic of the thoria-ceria mixture, not, however, to nearly so useful an extent. When cold, lanthana is, if dry, white. On standing it takes up water, swells, and assumes a brownish tinge. It is too fragile, after thus standing, for use as a mantle. The majority of the measurements made were confined to mixtures with thoria up to 50 per cent., because the higher percentages of lanthana would not hold together long enough.

Temperature Characteristics.

In Fig. 26 (V) is shown the temperature-concentration relation. It will be noted that the temperature is pulled down very much less rapidly by lanthanum than by any of the oxides thus far studied. The drop in temperature is, however, quite rapid for the first 5 per cent. addition.

Fig. 26.



Characteristics of thoria-lanthanum oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Constitution—emission isochromatics.
IV. Radiant luminous efficiency—constitution relation.
V. Constitution—temperature relation.

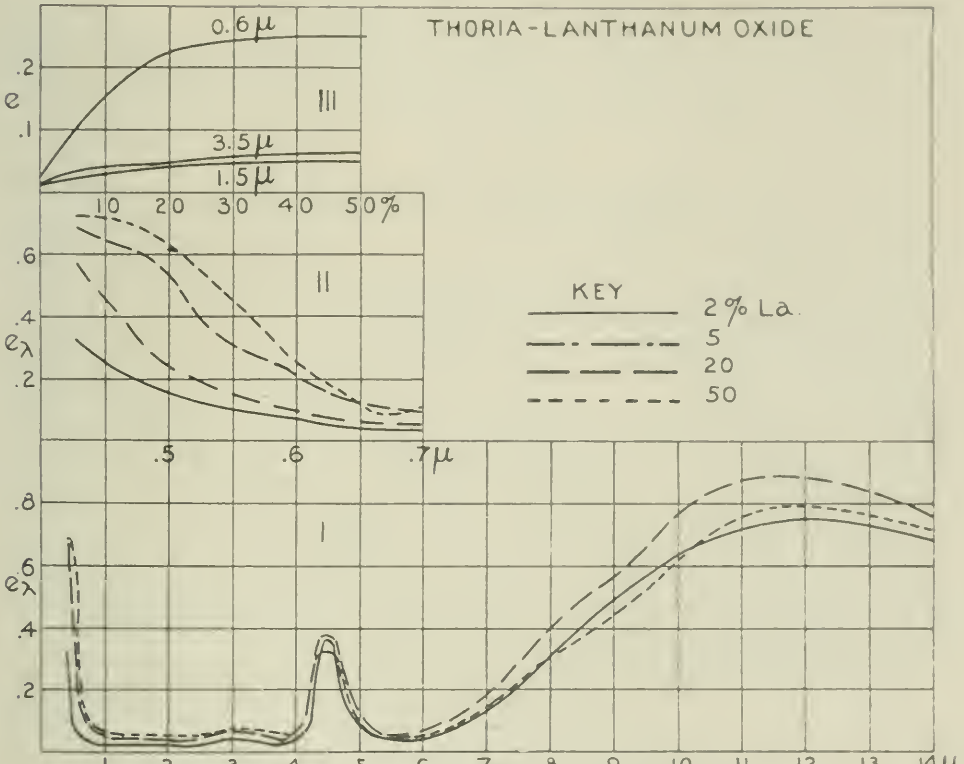
Radiant Luminous Efficiency.

The variation of radiant luminous efficiency with concentration is shown in Fig. 26 (IV). We have here the usual optimum occurring, but, unlike all the others so far, the optimum is not for very small percentages, but near the 50 per cent. point. The reason for this is evident when it is noted that the efficiency of pure lanthana is more than twice that of pure thoria, whereas in all previous cases the efficiency of the pure colorant has been below that of thoria, and the temperatures they assume very much lower than that assumed by lanthana. The behavior of lanthanum oxide is easiest described by noting that it might be replaced by a definite mixture similar in many respects to a thoria-ceria one, containing about twice as much colorant as enough to give the maximum efficiency.

Spectral Emission and Emissive Power Distribution.

These are shown for 2, 20, and 50 per cent. lanthana in Fig. 26 (I, II, and III) and Fig. 27 (I, II, and III). The noteworthy similarity with the thoria-ceria mixture is evident. From the emissive power curve it is seen that when hot this substance develops an absorption band in the visible region, just as does the ordinary Welsbach mantle. This band and the yellowing due to standing in the atmosphere are undoubtedly allied. Unlike ceria, however, this visible absorption band only assumes considerable values for high concentrations of lanthana, with which is associated sufficient general infra-red emission to pull the temperature down below the useful point.

Fig. 27.



Emissive-power characteristics of thoria-lanthanum oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emissive-power isochromatics.

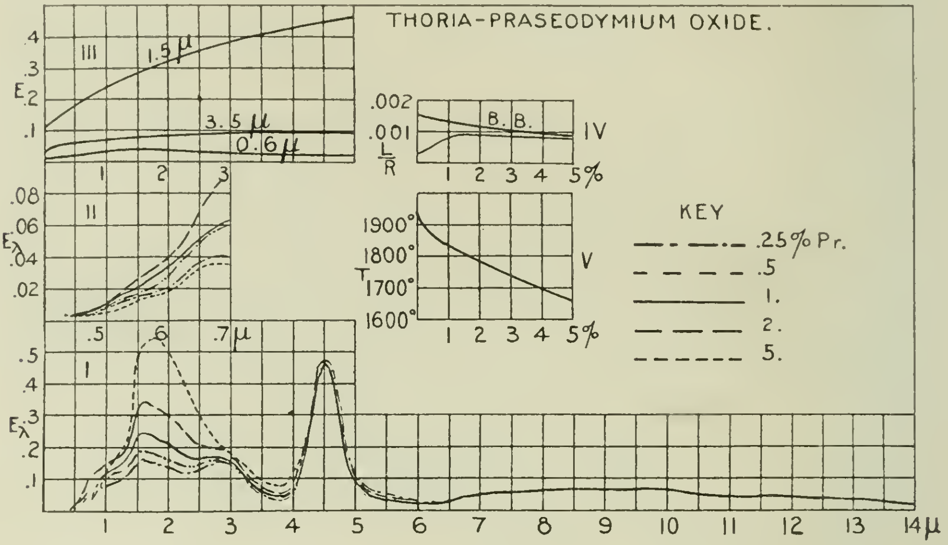
6. *Thoria-praseodymium Oxide.*

Mixtures of thoria with neodymium and praseodymium present a number of interesting phenomena, which, properly interpreted, must undoubtedly throw some light on the chemical relationship of the two and on the nature of the mechanism which produces their peculiar spectra. For reasons which will appear, they must be considered in the relation to each other, and, for simplicity's sake, the first one to describe is praseodymium.

General Physical Characteristics and Behavior.

Praseodymium oxide (Pr_4O_7) is dark brown or black. With thoria it gives dark brown mixtures, even when present only to the amount of a fraction of one per cent. This brown is, however, a function of the state of oxidation. When heated anywhere, except at the extreme outer edge of the flame (where it is most brilliant), it whitens, as is shown clearly by the ratio of hot to cold reflection power in Fig. 29 (IV) for wave-length 0.45 μ. It appears from this that for one per cent. of praseodymium, where the effect is a maximum, the increase in reflecting power on heating is no less than six times. This phenomenon is again demonstrated by withdrawing a mantle fragment from the in-

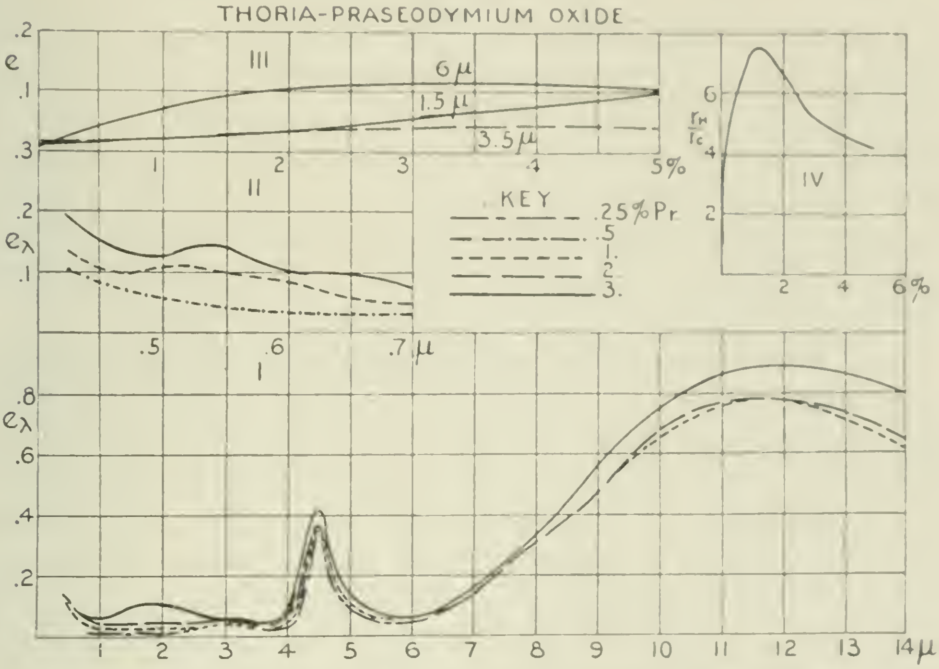
Fig. 28.



Characteristics of thoria-praseodymium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.
III. Constitution-emission isochromatics.
IV. Radiant luminous efficiency constitution relation.
V. Constitution-temperature relation.

terior of the reducing flame, from which it emerges white; by subjecting it to the cathode discharge, with the same effect, and finally by heating the oxide in a stream of hydrogen. This latter experiment is commonly reported as furnishing a *green* lower oxide. With the praseodymium used for this work, which was obtained from 4380 fractional crystallizations and used by Baxter in his atomic weight determination, the product is *white*.

Fig. 29.



Emissive-power characteristics of Thoria-praseodymium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, visible region.
III. Constitution-emission isochromatics.
IV. Ratio of hot to cold reflecting powers for wave-length 0.45 μ for various proportions of praseodymium.

Temperature and Luminous Efficiency.

The temperature composition plot of Fig. 28 (V) shows that praseodymium pulls down the mantle temperatures about as does ceria in its condition of maximum emissive power.

From the plot of radiant luminous efficiency against composition (IV) it is seen that the maximum efficiency never attains that of a black body at the same temperature.

Spectral Emission and Emissive Power Distribution.

These are shown in Fig. 28 (I, II, and III) and Fig. 29 (I, II, and III). The most striking point is the low visible emissive power, due to the whitening process, by reason of which is the failure, just noted, to attain a reasonable efficiency.

7. Thoria-neodymium Oxide.

Physical Characteristics and Behavior in General.

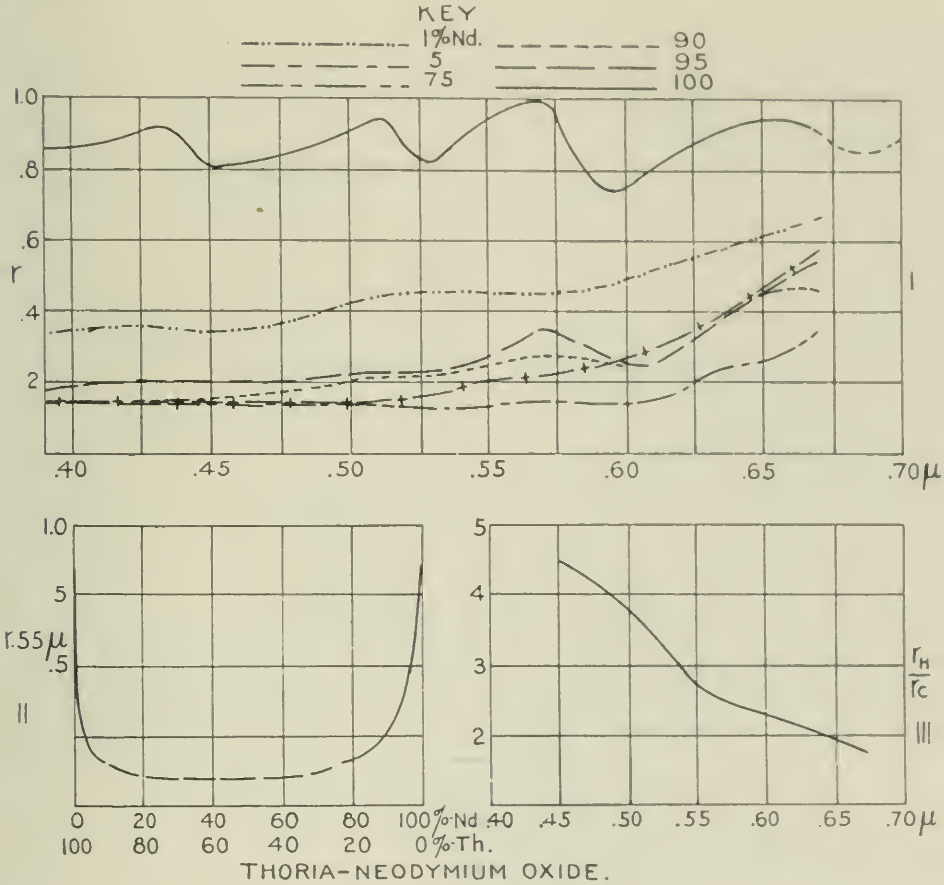
Neodymium is of extreme interest in optics from the fact that the absorption and emission bands of practically all its compounds are of extreme narrowness and sharpness. In the vast majority of solids, particularly the oxides, the absorption bands are wide and diffuse, with no well-marked beginning or end in the spectrum. This is true, as has just been seen, even with praseodymium, which is closely allied with neodymium. From the standpoint of light-production, neodymium oxide is of exceptional interest because its sharply defined absorption bands exemplify the kind of absorption which would be postulated for an ideal coloring material to be added to thoria in place of the somewhat extended absorption of the ceria band, narrow as that is.

Pure neodymium oxide, when freshly reduced, has a pinkish-white color, due to the presence of strong, narrow absorption bands in the green and yellow-green. On long heating this pink changes to a blue tinge, and the absorption band in the yellow-green spreads out into a multiple band in the yellow. Still another form, light brown in color, may be formed under certain conditions. Thus, if the pinkish oxide is gently heated in a quartz tube, through which air may pass, it turns to brown. A pure neodymium oxide mantle which had been laid aside for several months was found to have turned to this brown form, to return to grayish or bluish white, on igniting. The brown oxide formed by gentle heating in the manner described is reduced to the blue-gray form by contact with the reducing flame. The spectrum of this brown form appears continuous in a small spectroscope.

This brown coloration has been variously ascribed to impurities (*e.g.,* praseodymium) and to the formation of a hydrated oxide. The latter appears the more likely from our observation. At any rate, the occasional brown appearance of the pure oxide plays no apparent part in its radiating characteristics, as it is so entirely destroyed by the kind of heating a mantle gets in a flame. It is chiefly dwelt on here because of its possible connection with the extraordinary color phenomena exhibited by the thoria-neodymium mixtures, to be described next.

When neodymium oxide, which is only slightly off white, is mixed with thorium oxide, which is pure white, all the mixtures except those very close to the extremes of the series are *deep brown* in color, appearing, and, as will be seen, behaving, very much like the mixtures of thoria with praseodymium. In this brown mixture the typical banded spectrum of the neodymium disappears.

Fig. 30.

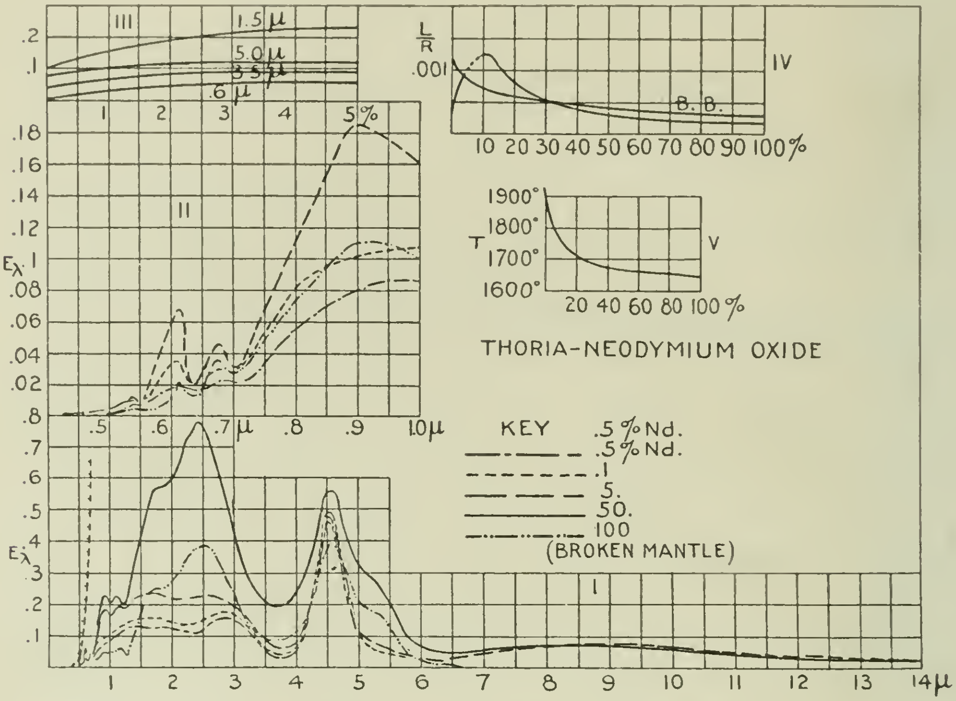


Reflecting-power characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of reflecting power (in terms of MgO = unity).
II. Reflecting-power-constitution isochromatic for 0.55 μ.
III. Ratio of hot to cold reflecting power through the spectrum for a 5 per cent. neodymium oxide 95 per cent. thoria mixture.

This phenomenon is illustrated in detail by the spectral reflecting power curves (in terms of MgO as unity) of Fig. 30 (I). It will be noted that the banded spectrum of the neodymium is, as it were, buried by the general absorption which gives the brown color. Fig. 30 (II), showing the variation of reflecting power with composition at wave-length 0.55 μ, exhibits the behavior even more graphically. It is remarkable that the addition of five per cent. of white thoria to 95 per cent. of nearly white neodymium oxide should result in a deep brown substance.

On heating these brown mixture mantles in the flame they are unchanged, judged by their appearance upon cooling, thus differing from the brown color sometimes shown by pure neodymium oxide. White hot, however, our measurements show that the brown coloration quite disappears. This is shown in one way by the ratio of hot to cold reflecting power through the spectrum for

Fig. 31.



Characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of emission.
II. Spectral distribution of emission, short-wave region.
III. Constitution-emission isochromatics.
IV. Radiant luminous efficiency-constitution relation.
V. Constitution-temperature relation.

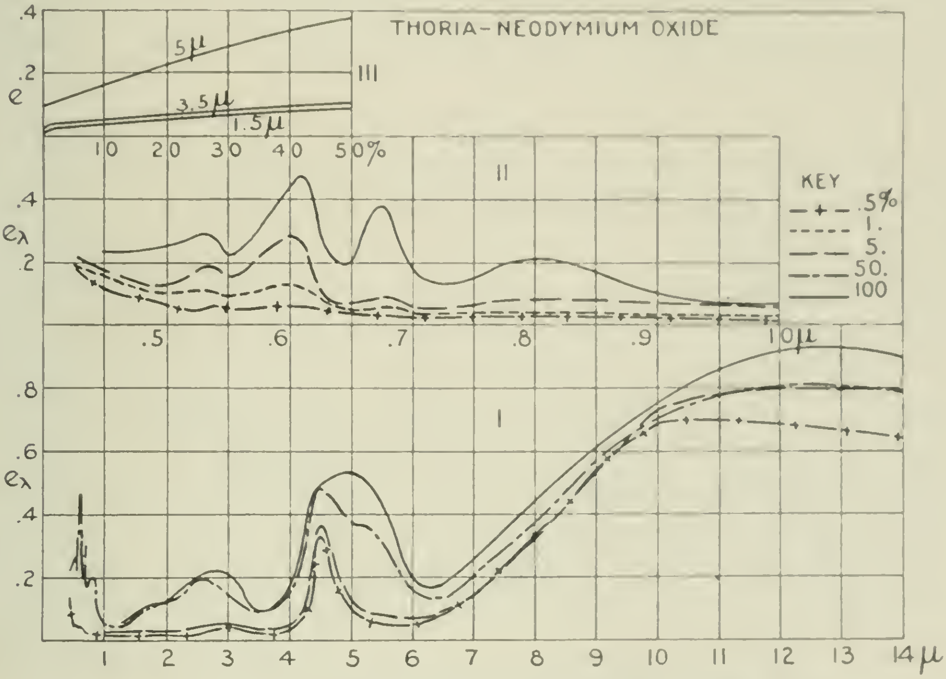
the 5 per cent. neodymium mixture, Fig. 30 (III). This ratio is obviously nearly complementary to the cold reflecting power, showing the elimination, while hot, of the special brown color. The spectral distribution curves show this quite clearly to be the case.

On heating in the cathode discharge, the brown mixtures behave just as the praseodymium mixtures; that is, they turn white, leaving the neodymium bands, and on heating in the air the brown color returns. Similarly, on heating inside the Bunsen flame and withdrawing, the brown color is destroyed, until reheating is done to the oxidizing flame.

Temperature and Radiant Luminous Efficiency.

These are exhibited in Fig. 31 (IV and V). The temperature drop is not excessive, being much less than for ceria. The radiant luminous efficiency rises to nearly double that of the black body at the same temperature, and as in the case of lanthanum, though not so conspicuously so, the maximum occurs for a fairly high percentage of neodymium admixture; namely 5 per cent., when the efficiency is 0.0013.

Fig. 32.



Emissive-power characteristics of thoria-neodymium oxide mixtures:
I. Spectral distribution of emissive power.
II. Spectral distribution of emissive power, short-wave region.
III. Constitution-emissive power isochromatics.

Spectral Distribution of Emission and Emissive Power.

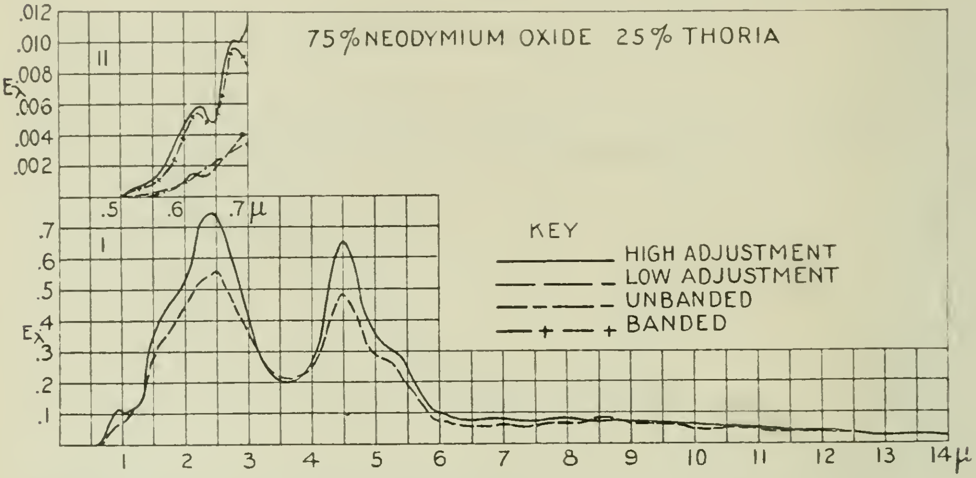
These are shown in Fig. 31 (I, II, and III) and Fig. 32 (I, II, and III). The striking characteristics of these are, first, the narrow emission bands shown not only in the visible spectrum, but in the infra-red; and, second, the banded character in the visible spectrum, and the regular progression, from low to high neodymium percentages, of the emissive power in the visible region. This latter clearly shows the destruction of the brown coloration in the hot mantle, in which the various mixtures exhibit intermediate properties between those of the ends of the series.

The emission bands peculiar to neodymium oxide have their maxima, as determined from the emission curves, at 0.54 μ, 0.612 μ, 0.675 μ, 0.92 μ, 1.12 μ, 1.75 μ, 2.2 μ, 2.42 μ, 5.25 μ.

Behavior in Different Kinds of Flames.

The whitening effect of the ordinary flame and the reducing flame have already been noted. An experiment connected with the same phenomenon is illustrated by Fig. 33 (II), in which, using a 75 per cent. Nd, 25 per cent. Th mantle, the flame was turned quite low, with the result (unbanded curve) that *the characteristic visible emission bands disappeared.* The emission spectrum is, in fact, of the character to be expected from a brown radiator.

Fig. 33.



Characteristics of neodymium oxide mixtures with different flame adjustments:
I. Spectral distribution of emission.
II. Spectral distribution of emission, visible region.

This unbanded spectrum was no longer possible to produce after the mantle had been burned for some time, as is indicated by the second set of curves shown, marked "High and low adjustment." The infra-red measurements made after the mantle had lost its original characteristics to some extent are shown in Fig. 33 (I), in which, nevertheless, a decrease in the near infra-red banded structure is still apparent.

Similarity of Neodymium and Praseodymium in Mixtures with Thoria.

From the data shown it is to be seen that the mixtures of neodymium and praseodymium with thoria have many points of similarity. They show the same color and kind of spectrum. They both whiten in reducing conditions. They might, in short, be mistaken for each other, especially in the lower percentages where the whitened neodymium mixtures show the neodymium bands only very slightly.

The suggested explanations noted above for the brown coloration of neodymium oxide—namely, that it contains praseodymium as an impurity, or is hydrated—appear inadequate for the present case. The amount of praseodymium present in the neodymium oxide used is believed to be less than 1 per cent., so that the 5 per cent. mixture, which is deeply colored, would have less than 1/20 per cent., and this quantity of the pure praseodymium scarcely colors the thoria at all. A coloration of neodymium oxide due to the presence of cerium has been previously noted by other workers, but was explained as actually due to praseodymium, for which the cerium was acting as an oxygen carrier. It appears from this present work that the occurrence of the brown mixture, with its continuous spectrum, is less likely to be due to impurity, particularly praseodymium, than to an altered configuration of the atoms. Further study of this point would be of great interest as possibly throwing light on the structure of the atoms of the neodymium compounds.

One observation made in obtaining the praseodymium mixture curves may be recorded, although it has not been repeated; namely, the appearance under one condition of adjustment of the shorter infra-red bands characteristic of neodymium.

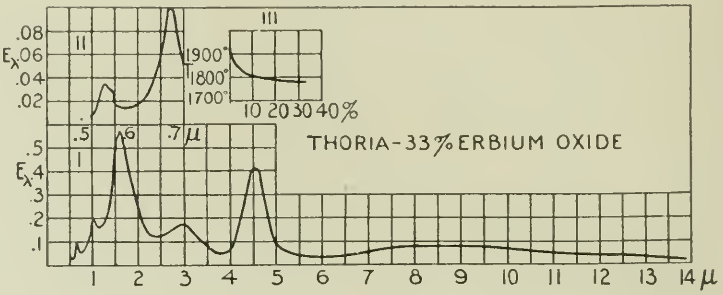
8. *Thoria-eribium Oxide.*

Complete measurements were made on only one mixture of erbium and thorium—namely, 33 per cent. erbium oxide—tests on a small sample of oxide having indicated that only in large percentages would the visible absorption bands of erbium oxide be broad enough to be of any promise for coloring.

Temperature measurements were made on this mantle and on a series of regular thoria-ceria mantles, to which had been added 1, 2, and 5 per cent. of erbium oxide in an experiment to see if the visible erbium band would add anything of value to the ceria band. These temperature points are shown in Fig. 34 (III). The general emissive power of erbia is low, resulting in a low temperature drop. The net result of adding erbia to the regular mantle, in spite of its small effect on the temperature, is a reduction in efficiency.

Spectral distribution curves of emission and emissive power are shown in Fig. 34 (I, II, and III). The narrow emission bands, similar in character to those of neodymium, are too narrow in the visible spectrum to aid substantially in light-production, and are offset by similar bands in the near infra-red.

FIG. 34.



Characteristics of thoria-erbium oxide mixtures:
I. Spectral distribution of emission, 33 per cent. erbia; 67 per cent. thoria.
II. Same, visible region.
III. Constitution-temperature relation.
IV. Spectral distribution of emissive power.

9. *Other Oxides.*

Besides the oxides for which data have been given, a number of others were investigated, which, for one reason or another, it did not appear profitable to attempt to measure in mantle form. Among them may be mentioned Barium, Cadmium, Calcium, Iron, Molybdenum, Strontium, Titanium, Tungsten, and Zinc, which exhibited volatilization or other defects.

Mention should be made also of platinum, which, applied in the form of a spray of platinic chloride, greatly increases the efficiency of the thoria mantle, but volatilizes so rapidly as to defy measurement and use.

10. *General Summary on Oxide Mixtures.*

It is shown by the data on the various mixtures of coloring oxides with thoria that their behavior is in general the same, differing, however, greatly in degree. In all cases an optimum mixture proportion is found. The value of the luminous efficiency at the optimum is greatest for ceria, below which come uranium oxide and neodymium oxide, both exhibiting an efficiency notably above the black body. The other oxides have at their optimum mixtures efficiencies too low to be of much interest.

The comparatively high efficiency of both the cerium and uranium oxides is due to the presence of a strong absorption band in the blue end of the visible spectrum. In the case of ceria this band is present only when the oxide is hot; in the uranium oxide it is present also in the cold condition. Other oxides—namely, manganese and praseodymium—bleach when hot, thereby partly losing their visible absorption bands, with consequent low efficiency.

It appears to be a general characteristic of all the coloring materials to rise in emissive power in the visible spectrum, indicating that the absorption bands, which give visible coloration, have their centres in the ultra-violet region. This is in agreement with their integral visual color, which is never blue, but always yellow or brown. To this is to be added the very general relative transparency in the infra-red from 1 μ to 5 μ. Both of these characteristics may be to some extent due to the mechanical structure of the mantle. Thus a roughened transparent substance, such as a piece of ground rock-salt, ceases to scatter light when the wave-length becomes long compared to the magnitude of the separate surfaces constituting the roughening; that is, in the infra-red. Also, the absorbing, or scattering, effect of small particles, in which state the coloring material may be present, decreases with increasing wave-length.

One of the most interesting facts brought out by the data is that the color characteristics of mixtures are not always simply additive. This is exemplified by the extraordinary behavior of the neodymium mixtures. In their case, however, the new coloration due to the mixture is present only in the cold condition. If it were known how such colors, different from those of the constituents, originated, a new field for the search for coloring materials might be opened.

IX. MISCELLANEOUS DATA.

Effect of Variation in Weight on Mantle Temperature.

As has been mentioned before, it was not feasible to determine for each mantle material investigated the weight to give the best compromise between luminous efficiency and mechanical properties. It is therefore of considerable importance to know how the temperature of a representative mantle varies with the weight. For this purpose a series of pure thoria mantles was made up, varying from 0.65 to 1.4 units in weight, and temperature measurements were made on them by the thermocouple method.

These measurements showed a nearly rectilinear relation between weight and temperature over this range, from 1930° for the lightest to 1860° for the heaviest mantle. Taking this as representative, it is evident that no important alteration in the relative standing of the various "bases" could be brought about by practical variations in their weight in mantle form. The nearest "base" to thoria—namely, magnesia (1840°)—might by a very considerable reduction in weight approximate the ordinary weight thoria mantle. It is, however, so inferior to the latter in mechanical strength and durability as to make this probability of small promise.

X. GENERAL DISCUSSION OF MANTLE EFFICIENCY AND ITS LIMITATIONS.

1. *Limitation to Radiant Luminous Efficiency Set by Attainable Temperature.*

Of the two variables at our disposal in selective temperature radiation—temperature, and the composition of the radiator—the first meets with a definite limitation in the case of the gas mantle in the temperature of the flame used for heating. With ordinary illuminating gas under the pressures common in commercial practice the attainable flame temperature is in the neighborhood of 2100° K. From the standpoint of light-production, this temperature is excessively low, being approximately that of the carbon filament, and lying some hundreds of degrees lower than the operating temperatures of the tungsten filament incandescent lamps. The radiant luminous efficiency of the black body at 2100° K. is about ½ per cent.; consequently the task of attaining an efficiency of only a few per cent. calls for a radiator of most pronouncedly selective character, even assuming that the flame temperature were taken by the radiator, which would be the case only if the latter's emissive power were of the order of 1 per cent. or less. With higher emissive powers the temperature assumed is, as has been seen, reduced, and this means a rapid loss of efficiency.

In order to learn approximately what improvement in efficiency might be expected if the regular mantle could be operated at higher temperature, a series of measurements were made on a mantle heated in a flame fed with various amounts of oxygen. Radiant luminous efficiencies were measured against optically read temperatures. The results are plotted in Fig. 13 (II), from which it appears that the efficiency of the radiation increases by about three times as the temperature rises from 1900° (regular mantle temperature) to 2100°. This rate of increase is approximately that of the black body, and if continued at the same rate would mean the attainment of an efficiency some twenty times greater at 3000°, which is somewhere near the temperature of operation of the nitrogen-filled tungsten lamp. Actually the rate of increase of efficiency could be made more rapid, because a progressively larger amount of ceria could be added to advantage at the higher temperatures. Such an efficiency (9 per cent.) is far above any present incandescent illuminant, and shows clearly that the actual low efficiency of the mantle is not so much the fault of its radiating properties as of the temperature to which it is limited. (This speculation says nothing with regard to the effect on the various heat losses were such a temperature attained, which will be treated separately below.)

2. *Limitations to Radiant Luminous Efficiency Set by the Temperatures Which the Mantle Materials will Stand.*

Aside from the question of means for attaining higher efficiency by higher temperatures, a vital matter to be considered is the effect of higher temperatures on the mantle materials.

The melting-point of thoria is given by Ruff [12] as 2440° C. (2713° K.), and that of ceria as 1950° C. (2223° K.). The former temperature is, of course, the upper limit of operation of a thoria base mantle, the lower that of a mantle containing ceria. There is good evidence, however, that ceria begins to volatilize at the ordinary mantle operating temperature. White and Mueller [13] have made observations on various mantles before and after burning for extended periods, and demonstrated the loss of ceria both by the variation in efficiency and by analysis. The increasing rate of candle-power depreciation with high-pressure burners is in line with their findings.

Closely allied to this question of melting and volatilization points is that of the physical strength of the mantle. This must be sufficient to give a useful life when subject to the average shocks of operation. The lighter the structure can be the higher the temperature it can take, as shown by the data on the thoria mantles of various weights, and the exact compromise between durability and efficiency must be determined from practical considerations.

3. *Radiant Luminous Efficiencies Theoretically Attainable with the Bunsen Flame and Thoria Base.*

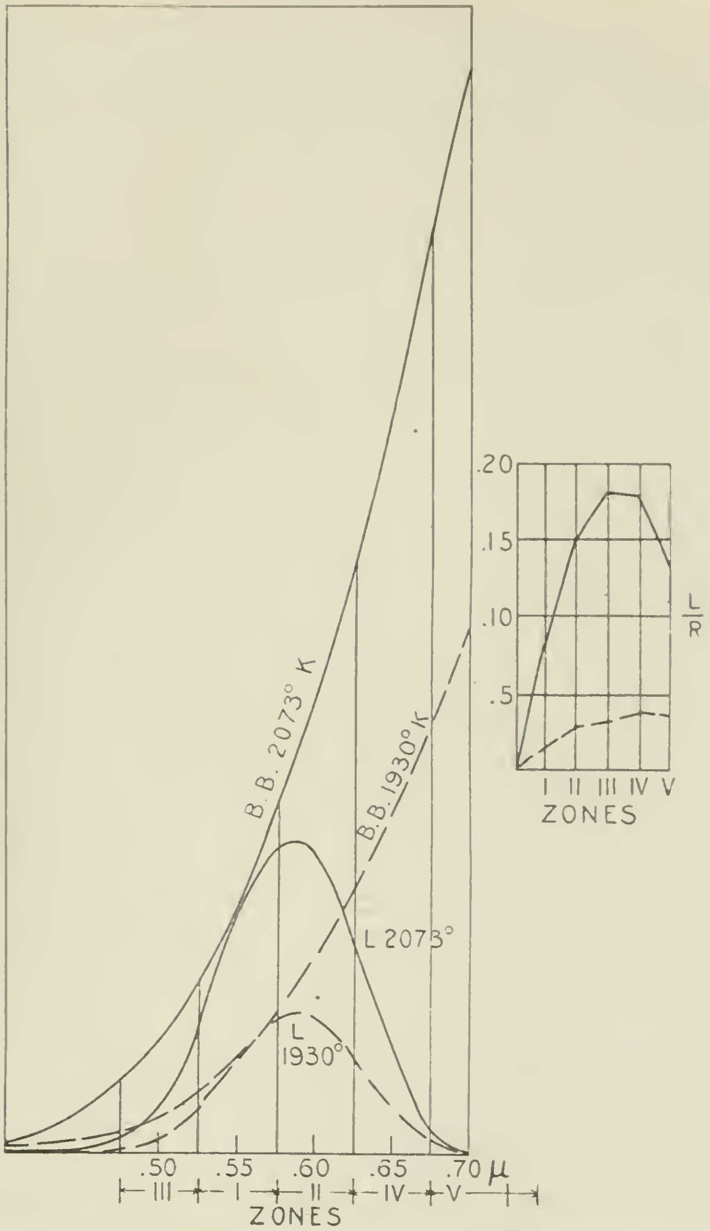
The attainment of the maximum possible efficiency, and the high efficiencies which have been suggested as possible from the materials of the present Welsbach mantle, would demand a freedom in the choice of radiating materials on the one hand, or of temperatures on the other, which we are far from realizing. It therefore becomes of interest, having established the limits of temperature at our disposal, and the characteristics of the radiator of lowest emissive power at our disposal (thoria), to investigate what efficiencies should be theoretically possible under the limitations thus set. All of the information necessary for such calculations is now at our disposal.

Let us first consider the possibilities of the Bunsen flame as a "base" for carrying a layer of selective radiator. We shall assume that its temperature is 1800° C. (2073° K.), and for its total emissive power we shall take the values resulting from using the actual radiation as measured in this investigation, which is 0.0116. We may further assume, without material inaccuracy, that the flame gives no appreciable light.

In Fig. 35 is plotted (BB) the spectral emission curve of the black body at 2073° K. for the visible region, and (L) the luminosity curve for the same black body. The ratio of the area of this luminosity curve to the area of the complete emission curve is the luminous efficiency of the black-body radiation at this temperature, and has the value 0.0032. Now, with this piece of information at our disposal, it is at once possible to calculate the contribution to the total radiation and to the total light of any emissive power in any part of the visible spectrum. The process is shown graphically in the figure. We first assume that to the colorless Bunsen flame is added a narrow zone of unit emissive power at the wave-length of maximum luminous efficiency. For ease of calculation we may take this band fairly wide, say 0.05 μ.

Call this zone I. The addition to the total radiant energy is the area of this zone lying under curve BB; the addition to the luminous energy is the area lying under the curve L, each, of course, being expressed in the unit fixed by the value of the area of curve L, above derived. Thus for zone I the area under BB, in terms of the area L = 0.0032, is 0.00175; the area under L is

Fig. 35.



Calculation of possible radiant luminous efficiencies using the Bunsen flame (full lines) and thoria (dashed lines) as bases.

0.00107. From this we get that the radiant luminous efficiency of the Bunsen flame + zone I of unit emissive power—*i.e.*, the ratio of the luminous to the total energy—is

$$\frac{.00107}{.0116+.00175}=.08$$

Adding by this same process successive zones on each side of the original one of lower and lower luminous efficiency, we obtain for the luminous efficiencies as follows:

Bunsen flame + Zone I	0.084
Bunsen flame + Zone I + Zone II	.159
Bunsen flame + Zone I + Zone II + Zone III	.169
Bunsen flame + Zone I + Zone II + Zone III + Zone IV	.166

Beyond this point the added zones lying largely or wholly in the infra-red or ultra-violet contribute to the total energy and not to the luminous energy, and reduce the efficiency, which goes through a maximum at approximately 17 per cent.

This efficiency is subject to a certain reduction, due to the fact that the total radiation is approximately doubled by this additional emissive power, and such an increase, as we have seen, reduces the temperature of the radiator. From the experimental curve of Fig. 10 (I) we may estimate that the temperature reduction would be to about 2000° K. Assuming that the resultant drop in efficiency is approximately that which a black body would suffer by such a lowering of temperature, we make a deduction of 20 per cent., leaving an efficiency of about 13 per cent.

It is obvious that this calculation, to be highly accurate, should be carried through by quite small steps, and the change of temperature introduced at each step, but the figure obtained by the rougher method here used is substantially accurate—certainly sufficiently so for our present purposes.

It next becomes of interest to study by the same method to what efficiency we are restricted if no better base than thoria is found, assuming the possibility of adding a colorant of the ideal character represented by the zone just assumed added to the Bunsen flame. We may take, for the temperature assumed in the flame by the thoria base, 1930° K.; for its emissive power, 0.043; for the efficiency of the black body at this temperature, 0.0018, the light given by the thoria being small enough to be negligible. Proceeding as before, we obtain for

Thoria base + Zone I	0.0135
Thoria base + Zone I + Zone II	.029
Thoria base + Zone I + Zone II + Zone III	.0296
Thoria base + Zone I + Zone II + Zone III + Zone IV	.034
Thoria base + Zone I + Zone II + Zone III + Zone IV + Zone V	.032

As before, this efficiency must be corrected, owing to the temperature reduction caused by the radiation increasing from 0.043 to about 0.05 that of the black body at 1930°. Judging by the regular thoria-ceria mantle, this reduction would probably not amount to more than 30°, resulting in about 15 per cent. loss of efficiency, leaving a net possible radiant luminous efficiency of 0.029. This is approximately *three times* the radiant luminous efficiency given by ceria as a colorant (making the comparison with the efficiency attained in the brightest part of the mantle, where alone the assumed temperature applies).

A point of considerable interest which comes out of this study is that the maximum efficiencies thus calculated are obtained with very nearly the complete visible spectrum endowed with full emissive power. If the base were absolutely transparent and non-emissive, the most efficient coloring medium would be one with emissive power restricted to the middle, most efficient part of the spectrum; that is, one giving a yellow-green light. With the presence, however, of invisible emission in the base, a considerable quantity of visible radiation may be added, even though not all of good efficiency, before the increment to the total radiation, which is the denominator of the efficiency fraction, begins to increase at the same rate as the visible part.

It appears, from this calculation, that by using the present thoria base, without any increase of flame temperature, a very substantial increase of luminous efficiency could be obtained, provided a coloring material of the proper characteristics were available. The desired colorant would differ from ceria in two respects: First, it would add nothing to the radiation in the long wave-region near $2\ \mu$; and, second, the absorption band which is responsible for the visible emission would be sharply defined on the red side, more like the bands of neodymium than the gentle slope of the ceria band. Of these two differences, the second would be of the greater importance, for, with everything else left the same in the ordinary mantle, any increase in the emissive power near 0.6 μ (which is only about 20 per cent.) at the expense of the emissive power at the red end of the visible spectrum and near infra-red would appear directly in the efficiency.

4. *Heat Losses in the Burner and Mantle-lighting Unit. Hydraulic Analogy.*

Attention has been directed chiefly in this investigation to the study of the radiating properties of various materials, and the information desired has been the luminous efficiency of their radiation. The methods of study employed give, however, information which is of interest and value on the sources of inefficiency of the whole mantle-burner combination.

Thus, as has been pointed out elsewhere, the ratio of the total luminous efficiency to the radiant luminous efficiency gives the radiational efficiency, or efficiency of transformation of the applied energy into the radiant form. The total luminous efficiency obtained from the lumens per watt rating and the mechanical equivalent of light is 0.0019. Dividing this by the radiant luminous efficiency (as obtained in this work for the horizontal direction) gives 0.44, or an efficiency of transformation of applied energy into radiant energy of less than one-half. Using an earlier figure, obtained by Karrer for the mantle with a glass chimney—namely, 0.019—this efficiency drops to about one-sixth. Without radiant luminous efficiency figures for the whole radiation (instead of in one direction only) it is not possible to calculate the radiational efficiency accurately in this way, but it is clearly quite low. A more accurate method of calculating the losses, which are obviously those due to convection and conduction, is obtained by making a heat balance for the mantle and burner. If we assume that the products of combustion leave the mantle at the temperature of the latter, we can, by knowing the specific heat of these products and their amount, calculate the amount of energy carried away by them, thus getting the convection losses, which are probably the greater portion of the losses.

The result of carrying through these calculations for a mantle at several different temperatures is shown in Fig. 9 (III). A gas of 630 B.t.u. per cubic feet was assumed, and the specific heats in B.t.u. per cubic foot of gas consumed per degree centigrade at various temperatures were plotted from standard tables. The calculation then consisted in comparing the ratio of this specific heat to the initial (630).

It appears, from this figure, that the energy loss by convection is, for the ordinary mantle at about 1900° K., close to 75 per cent. Furthermore, this loss is different at different temperatures, decreasing with lower temperatures, being only about 45 per cent. for the ceria mantle temperature (1350°). Hence any increase in efficiency sought by increasing mantle temperature is, other conditions being unchanged, offset in large degree by the increase in convection losses.

The accuracy of this curve (and the validity of the assumption that the convection losses are practically the total losses) is indicated by the experimental points (circles) obtained by Kingsbury during an earlier study of radiant heaters by a calorimetric method. This decrease of radiation with increasing temperature is in entire accord with the relationship between temperature and total radiation found in connection with the measurement of temperature by total radiation.

It is evident, from a study of the figures used in the calculation, that a large part of the convection loss is due to the volume of inert nitrogen carried through the flame. The effect of this is shown graphically by the additional dashed curve of Fig. 9 (III) calculated for the condition that combustion takes place in oxygen instead of air. The losses are less than half as great, but increase with increasing temperature as with air.

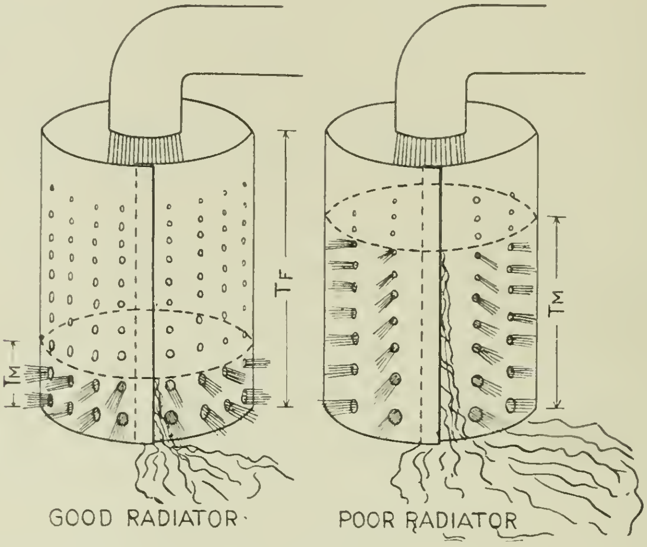
The whole behavior of the burner and mantle may be represented by an extension of the hydraulic analogy suggested by Wood [14] for the mantle alone.

We can imagine the mantle to be represented by a vertical cylindrical tank into which water is flowing at a constant rate from a tap (Fig. 36). The wall of the tank is to be imagined as perforated by holes of various sizes. The water which squirts out through these holes is the radiation, and the various sizes of holes represent various wave-lengths. If the smaller holes are more numerous at the top of the tank, then the higher the water rises the more will squirt out through the smaller holes, thus copying the behavior of a material radiator, water *height* being taken to represent *temperature*.

If now we take a tank containing many holes, the water will not rise very high, and, conversely, in one with only very few holes the water will rise higher, thus copying the behavior of mantles of high and low emissive powers, in so far as their temperature characteristics are concerned. If the holes are all made small, only squirts of small size will be present, and the water will rise higher than if holes of all sizes are present, thus copying the characteristics of a selective radiator like the mantle.

In order for this tank to represent the behavior of the mantle with respect to the amount of radiation, it is only necessary to imagine a vertical seam of the tank to have been left unsoldered, so that a bad leak is present, to represent the convection and conduction losses. The higher the water rises, as when the radiating holes are made few in number, the more is lost through the leaky seam, and so the less is " radiated " through the holes. Obviously, with a constant rate of supply the advantage of increased " temperature " is being more and more offset by the leakage.

Fig. 36.



Hydraulic analogy of mantle and burner: T_m=Mantle temperature. T_f=Flame temperature.

To go back to the actual mantle, it appears that by eliminating the convection loss the temperature attainable and its availability for producing radiation would be much increased. This is what occurs when the mantle is heated *in vacuo*. If, for instance, a ceria mantle and a thoria mantle are receiving energy at the same rate from the cathode stream, the ceria mantle saves through elimination of convection losses and diverts to radiation about 80 per cent. more than it does of the same energy supplied by the flame; the thoria mantle, on the other hand, retains for radiating purposes *four times* what it does when heated by the flame. The effect of this on the temperature attained could be found only by studying the relation between total radiation and temperature in the mantle materials. A black body radiating n times the energy of the same body at the temperature T must have the temperature

$$\sqrt[4]{nT}$$

For 80 and 400 per cent. the increase in temperature would be approximately 15 and 40 per cent. respectively. The latter increase on 1900° would correspond to an enormously greater increase in luminous radiation than the former on the lower temperature of 1350°.

It has already been shown how the failure of ceria to color the mantle, in the cathode discharge, explains the lack of superiority of the ceria-thoria mixture over pure thoria under those conditions. The large reduction in convection losses in the vacuum tube explains why pure thoria should be so overwhelmingly superior to pure ceria in the cathode discharge, although nearly alike in the flame, thus giving a complete explanation of the differences in behavior, which have been a long-standing puzzle.

5. *The Total Luminous Efficiency Attainable with the Bunsen Flame as the Source of Heat.*

With the information on convection losses just obtained, it is of interest to consider again the limitations of the Bunsen flame as a source of heat for producing light. Thus far we have considered merely the *radiant* luminous efficiency attainable by adding an ideal colorant to the flame. This has been found to be approximately 13 per cent. with air, accompanying a temperature of about 2000° K. In order to get the *total* luminous efficiency of the burner and mantle, this figure must be multiplied by the radiational efficiency for 2000° K. as given in Fig. 9 (III); namely, 20 per cent. The total luminous efficiency thus derived is 2.6 per cent.

This figure represents the maximum possible efficiency attainable by heating a mantle in the customary manner by means of a

Bunsen flame. While over thirteen times that of the present mantle gas light (0.0019), it is yet very low as an absolute efficiency. It is, in fact, below the value already attained by the nitrogen-filled tungsten lamp (0.032). It must be remembered, however, in this connection, that the process of obtaining the stored energy from coal by the production of gas is much more efficient than is the process, employing boiler and engine, used for transforming the energy to electrical form. As a consequence the efficiency measured from the coal pile is not greatly different for the two kinds of light.

XI. GENERAL SUMMARY.

The investigation here described, in so far as it deals with the radiating characteristics of the incandescent mantle, constitutes chiefly an extension of the work of Rubens on the thoria-ceria mixtures, to a large family of such combinations. It exhibits the Welsbach mantle of commerce simply as one of a group of possible combinations of radiating materials, behaving according to the same general laws, but remarkable among them for the degree to which the characteristics of selective radiation are exhibited.

A more detailed study has been made than any heretofore on the behavior under various conditions of the absorption bands to which the enhanced visible radiation of the more efficient mantles are due. While no *explanation* has been found for the occurrence of the visible absorption bands of ceria and other materials—a question to be solved only by an intimate knowledge of the structure of matter—the information learned as to the conditions under which they appear and disappear has made possible a rather complete explanation of some long-standing enigmas, notably that of the different behavior of the mantle in flame and cathode-discharge heating.

Another line of investigation has here been taken up apparently for the first time in any detail; namely, that of the energy relations holding with flame heating of radiating materials. As a result of the study it has been possible to fix with some definiteness the possible attainable efficiencies of gas-light production by present methods. These, while low, are still many times any now reached.

NOTES.

[1] Rubens, *Annalen der Physik*, 20, 3, p. 593 (1906).

[2] For instance, Wood's "Physical Optics" or Burgess and Le Chatellier's "High Temperature Measurement." An excellent review of mantle theories is given by Fulweiler, *Trans. I. E. S.*, iv, p. 65, 1909.

[3] See Ives, "The Units and Nomenclature of Radiation and Illumination," *Astrophysical Journal*, January, 1917, p. 39.

[4] Ives, "Establishment of Photometry on a Physical Basis," JOURNAL OF THE FRANKLIN INSTITUTE, October, 1915, p. 409.

[5] Ives and Kingsbury, "Physical Photometry with a Thermopile Artificial Eye," *Physical Review*, November, 1915, p. 319.

[6] White and Travers, *Jour. Soc. Chem. Ind.*, 15 (1902), p. 1012.

[7] Langmuir, *Physical Review*, xxxiv, p. 401 (1912).

[8] Féry, *Ann. de Chem. et de Phys.*, 27 (1902), p. 433.

[9] See Levy, "The Rare Earths," p. 177.

[10] Campbell-Swinton, *Proc. Roy. Soc.*, 65 (1899), p. 115.

[11] Killing, *Journ. für Gasbel.*, 50, p. 90.

[12] Ruff, *Zeits. anag. Chem.*, 82, p. 373 (1913).

[13] White and Mueller, *Jour. Gas Lighting*, 83 (1903), p. 504.

[14] Wood, *Physical Review*, xxiv, p. 437 (1907).

Manufacturing Destroyers. H. O'HIGGINS. (*The Official Facts.* Committee on Public Information, Washington, D. C., September, 1918).—It formerly took two years to build a fast destroyer. One has just been built in a little more than two months. These craft, costing two million dollars each, have the engine power of the old battleship *Maine* and the speed of a motor boat. Experience has shown that they are the most effective weapon against the submarine. At the outbreak of the war we succeeded in completing one in eight months instead of two years. Then, with the speeding up of production, another was completed in six months. Now, in the Mare Island Navy Yard, the destroyer *Ward* has been launched 17½ days after its keel was laid, and it has been completed in seventy days.

There is no magic in this enormously increased rate of production; we are now not building destroyers, we are manufacturing them. The process by which the *Ward* was manufactured is a machine process, by which we can produce at the same rate, as many destroyers as we need. The steel parts are prepared, in various plants, all over the country, in accordance with standardized plans. These parts are assembled in navy yards, put together at the docks, swung into position and riveted in place by a force of men working night and day. In other words standardized destroyers are being turned out as standard automobiles are turned out, in quantity production. The Navy Department reports that one flotilla of these destroyers, having steamed a million miles on patrol, has protected 86 convoys and 717 single vessels, and fought 81 submarines without any loss to the destroyers or to the vessels which they escorted.

The Remelting of Aluminum Pig in the Electric Furnace. D. H. MILLER. (*Chemical and Metallurgical Engineering*, vol. 19, No. 5, September 1, 1918.)—About one-half of the total amount of the aluminum used in this country is manufactured in the plant of the United States Aluminum Company at Massena, New York. Here the pig metal as it comes from the reduction plant is remelted for the purpose of casting it into ingots or rolling billets. A number of aluminum alloys are also made and the metal heat treated in the electric furnace after having been rolled down into rods or conductors. The object of this remelting is to cleanse the metal by removing in this manner the slag and scum contained from the reduction process. After the remelting there is a distinct and marked difference in its appearance, as it loses its dull finish and is much brighter. Since a very great quantitiy of aluminum is handled at this plant, even the smallest saving in metal loss is important and soon manifests itself in the aggregate savings. Hence, with the idea of experimenting with just what could be done in the way of effecting savings as well as in improving the quality of the metal, the United States Aluminum Company installed electric furnaces both for remelting and heat-treating the metal.

The furnace selected for remelting is a stationary resistance type and has a bowl-shaped hearth capable of holding three to four tons of molten metal. It is rated at 500 KW. and designed for single-phase 25-cycle operation. When running continuously the furnace can melt one ton per hour, which is topped into graphite crucibles holding about 125 pounds. The daily output of the furnace is twenty tons. The advantages which are secured by the use of the electric furnace are summed up by Mr. H. M. Hall, Superintendent, as follows: (1) The electric furnace replaced an oil furnace burning crude petroleum oil which produced large losses, particularly in the case of alloys containing volatile constituents, such as zinc. (2) The electric furnace gives much more uniform mixtures with much less loss. (3) The cost of electric power compares very favorably with the increased cost of fuel oil which was becoming prohibitive. (4) Savings are effected by the use of the electric furnace in that the metal losses are less and the thermal efficiency greatly increased. (5) Where coal-fired furnaces are used, there is a saving of one or two men in favor of the electric furnace. (6) There is also a saving in space required for a given weight of metal melted in favor of the electric over the coal-fired furnace. (7) The electric furnace is much cleaner and cooler to operate than is the case with an externally-fired fuel furnace. It is evident that while improved quality of product was the end sought, economy of operation resulted from the use of electricity as its heating medium.

A SURFACE HAVING ONLY A SINGLE SIDE.*

[ADDENDUM.]

BY

CARL HERING, D.Sc.,

Member of the Institute.

In the August, 1918, issue of this JOURNAL, page 233, the writer described an odd form of surface which differs from the usual surfaces in having only one side, and in a mathematical sense must therefore be considered non-polar or unipolar.

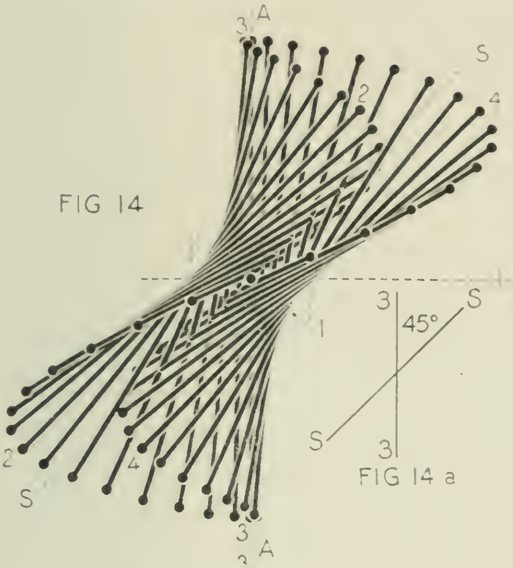


FIG 14

FIG 14 a

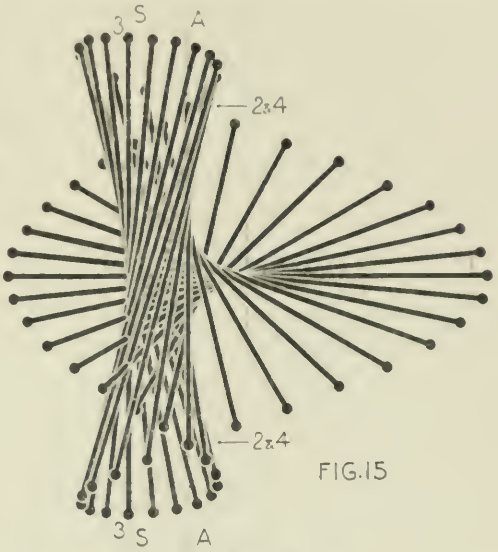


FIG.15

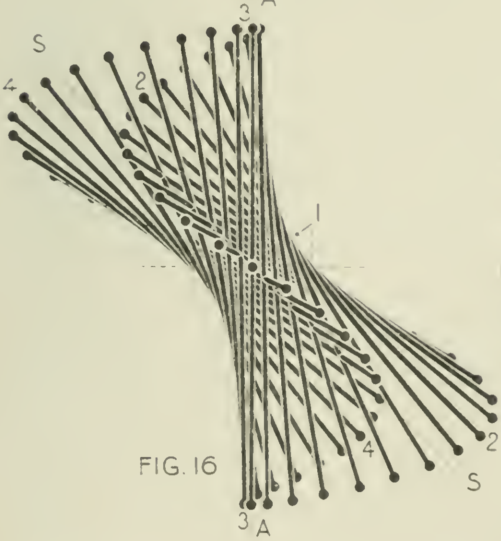


FIG. 16

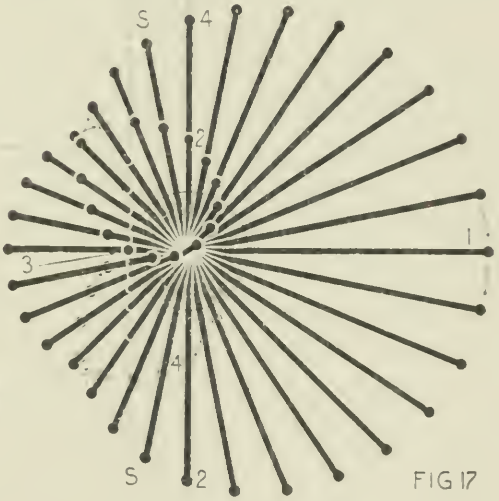


FIG 17

Since then the writer has made a further investigation of the algebraic equation of this surface which was added to the former article just before going to press, and has endeavored to give a better conception of this surface by means of some additional drawings.

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* Communicated by the Author.

It is difficult to show this peculiarly curved surface by means of flat drawings other than stereoscopic views. Nor can it be shown by a shaded drawing as though made of cardboard, as it is in a sense hollow, or more correctly, doubly hollow; it should be shown as though transparent. The accompanying diagrams, Figs. 14, 15, 16 and 17, were therefore drawn accurately to scale showing it in the form of a succession of lines or rods representing its rectilinear elements in their successive positions in developing this surface. This gives the desired effect of transparency, and by making use of the conventional shading and the knobs at the ends, and by showing the self-intersection, the desired stereoscopic effect is at least approached.

The two slanting, neighboring, trumpet-shaped holes or passages through it, which in a sense make it doubly hollow, unfortunately cannot be shown as openings in any of these drawings, each of which is taken perpendicularly to some one of the four cardinal positions of the elements. These passages can be seen best in Fig. 16 when one conceives that the row of knobs through the middle represents a series of elements forming a partition which divides the tubular interior into two oblique passages.

In all of these figures the four cardinal positions, 1, 2, 3 and 4 of Fig. 1, are marked with their respective numbers. *AA* represents the central axis and *SS* the line along which this surface interests itself. The lengths of the elements were made equal to four times the diameter of the circular directrix, which is shown in Fig. 17; beyond that distance there is nothing more of interest.

Fig. 14, corresponding to the former Fig. 4, is a view in line with position 1 of Fig. 1, taken from the right, while Fig. 16, corresponding to the former Fig. 6, is the same taken from the left. Fig. 15, corresponding to the former Fig. 5, is taken in line with the plane of 2 and 4 (which two positions coincide in this view), hence is a view of Fig. 14 from the left, or of Fig. 16 from the right; it shows the two trumpet-shaped and the two fan-shaped parts. Fig. 17 is the top view of Fig. 15 in line with the axis; each of the positions in this view necessarily represents two diametrically opposite elements which therefore partially overlap; the knobs indicate the ends of these superimposed elements.

From the group of rectilinear cross sections, Figs. 8 to 13 in the former article, one was overlooked; it is the vertical section through the position 3 and the line of intersection SS, hence perpendicular to position 1; it is a cross section of Fig. 14 parallel to the plane of the paper and slightly to the rear of it; it is shown on a reduced scale in the supplementary Fig. 14a. It is one of the simplest of these cross sections.

In the algebraic equation given in the former article there is an error in two of the signs; the sign before ryz should be − and not +, while the one after yz should be + and not −. Dr. C. P. Steinmetz subsequently reduced it to the following form:

$$y(y+z)^2 - y(r+x)^2 + 2x(y+z)(r+x) = O$$

The writer has reduced it to the following, which he believes to be its simplest form:

$$y(x^2+y^2+z^2-r^2) + 2z(x^2+y^2+rx) = O$$

In these the geometric centre of the surface is at the origin of the system of coördinates, and the circle of radius r is in the plane of X and Y; hence the axis A in the figures is the axis of coördinates Z; position 1 lies in the positive direction of X. Both of the angular motions are assumed to be clockwise, as shown in Fig. 1; when one is clockwise and the other anti-clockwise the only change in the latter equation is that the sign before the $2z$ is negative.

Inserting in this equation $x = -r$ gives $y = -z$, which proves mathematically that the self-intersection of this curved surface is a right line lying in a plane perpendicular to position 1 and through position 3; and that it makes an angle of 45° with the horizontal or vertical, as shown in Fig. 14a. The result $y = -z$ also shows that it lies in the quadrants $+z$, $-y$, and $+y$, $-z$, all of which will be seen to be confirmed in the drawings by the line SS, and was first noticed by the writer in the models.

In all the above the clockwise direction was assumed for both of the angular motions, as described in connection with Fig. 1; if both directions are anti-clockwise the results will, of course, be the same as before; but if one is clockwise and the other anti-clockwise this line of self-intersection SS will lie in the other pair of quadrants, that is, will be at right angles to its position in Fig. 14a, and its equation will then be $y = z$, as the sign before $2z$ in the above equation is then – instead of +. These two forms of this surface bear the same relations to each other as a right- and a left-handed screw thread.

As an additional proof of this curious rectiliear self-intersection, the writer started with the assumption that it was this 45° right line and developed the equation of a surface generated by the movement of a right line so that it always touches: *(a)* a circle, *(b)* the axis of the circle, and *(c)* a right line making an angle of 45° with the plane of the circle and lying in a plane tangential to the circle. The equation thus obtained was identical with the second one given above. The same surface may therefore be correctly defined in either way.

The above equations were furthermore tested by deducing from them the cross sections, Figs. 8, 9 and 10. Making $z=0$ gives the equation of the section Fig. 8. Making $y=0$ gives the equation of the section Fig. 9. Making $x=0$ gives the equation of the section Fig. 10.

Using polar coördinates in the plane of the circular directrix (the plane of X and Y, see Fig. 17), and letting a be the angle of the projection of an element on that plane measured clockwise, R the radius vector of the projection of any point of that element, and z as before the vertical distance of that point above or below this plane, then the equation at the end of the former article (after correcting the signs) reduces to the much simpler forms:

$$z=(r-R)\tan\tfrac{1}{2}a$$

$$z=(R-r)\cot a-(R-r)\ \text{cosecant}\ a$$

from which the value of z of that point may be easily determined. The first expression is the more convenient for arithmetical calculations, care being given to the signs and to the directions of rotation. The second expression gives a completely graphical and very simple solution, for by striking an arc through the point in question with a radius of $R-r$, using as a centre the point of intersection of the radius vector R with the circular directrix, and drawing the necessary cotangent, the quantities $(R-r)\cot a$ and $(R-r)$ *cosecant* a, are given graphically, and as the lines representing them intersect, their difference, namely the desired value of z, is readily measured off. "Descriptive geometry," so-called, provides another completely graphical solution.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A PORTABLE APPARATUS FOR DEVELOPING MOTION-PICTURE FILM AT NORMAL AND AT HIGH TEMPERATURES.[1]

By J. I. Crabtree.

[ABSTRACT.]

By an application of the apron method of developing films as adopted in the Kodak Film Tank outfit, a portable and compact apparatus has been devised for the development of motion picture film, while by applying the method of developing at high temperatures as described in Communication No. 62 (B. J. 1917, p. 555), it is possible to develop motion picture film up to temperatures as high as 95° F. In view of this and the portability of the apparatus it is hoped that the method will be of particular value to explorers traveling in tropical countries who must develop their film as soon as possible after exposure and under existing conditions.

The apparatus consists of a celluloid apron somewhat wider than the width of motion picture film, and a suitable reeling apparatus and developing tanks, the film being wound onto the apron, developed, fixed and washed in the apron, and finally dried by transferring to a collapsible frame rack in the usual way.

The formula for the T_6 developer recommended is as follows:

	Avoirdupois	Metric
Paraminophenol hydrochloride or Kodelon	105 grains	7 grams
Sodium Sulphite (desiccated)	1 oz. 300 grains	50 grams
Sodium Carbonate (desiccated)	1 oz. 300 grains	50 grams
Water to	32 ozs.	1000 c.c.

The time of development with this developer is 1½ minutes at 95° F., but if this is too short for convenience in working, the time may be extended to three minutes by adding 10 per cent. sodium sulphate to the developer before use.

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* Communicated by the Director.

[1] Communication No. 74 from the Research Laboratory of the Eastman Kodak Company, published in *Mot. Pic. News*, 1918, p. 1582 and p. 1742.

After developing, rinse for a few seconds and fix in the following chrome alum bath at temperatures up to 85° F.

	Avoirdupois	Metric
Hypo	7 ozs.	200 grams
Sodium Sulphite (desiccated)	1 oz. 175 grains	40 grams
Chrome Alum	2 ozs. 350 grains	80 grams
Acetic Acid (28 per cent)	150 minims	10 c.c.
Water to	32 ozs.	1 liter

Dissolve the sulphate and chrome alum together and add to the hypo solution, finally adding the acetic acid.

At temperatures up to 95° F. the following formalin bath should be employed:

	Avoirdupois	Metric
Hypo	9 ozs.	250 grams
Sodium Sulphite (desiccated)	1 oz. 350 grains	50 grams
Formalin (formaldehyde 40 per cent)	4¼ ozs.	125 c.c.
Water to	32 ozs.	1 liter

First dissolve the hypo, then the sulphite, and finally add the formalin.

When developing at high temperatures it is very necessary to maintain the temperature of the developer, fixing bath, and wash water the same, otherwise if the film is transferred from a hot to a cold solution, or *vice versa,* reticulation of the gelatine coating is liable to occur.

By a slight modification the apparatus could be made suitable for daylight developing, though this would necessitate the carrying of a collapsible box to fit around the reeling apparatus.

The author is indebted to Mr. S. Tulpan for his valuable assistance in the carrying out of the various experiments.

THE EFFECT OF SIZE OF STIMULUS ON THE CONTRAST SENSIBILITY OF THE RETINA.[2]

By Prentice Reeves.

[ABSTRACT.]

THE experiments were made with the visual sensitometer devised by Nutting and are of the nature of a continuation of the work of Nutting and Blanchard on the sensitometry of the eye.

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[2] Communication No. 70 from the Research Laboratory of the Eastman Kodak Company, published in *J. Optical Society of America,* 1917, p. 148.

Five contrasts and six stimulating areas or test spots were chosen. The contrasts were 0, 0.39, 0.67, 0.87 and 0.97. The sizes of the illuminated test squares were 2, 5, 7, 25 and 30 mm. Neutral film of the necessary opacity placed over half of the square furnished the contrasting areas. For each size of square and for each contrast, the times necessary to see the illuminated area for a number of field brightnesses were noted, from which a double series of curves connecting field brightnesses with time of appearance are obtained.

The Fechner fraction, dB/B, is next obtained and plotted as a function of field brightness. A family of such curves is found by varying the adaptation time from 0 to 60 seconds.

Lastly, a simple application of these results is made to the problem of aeroplane detection. The writer concludes that if an aeroplane of 40 feet spread, with a contrast against the sky of 0.97 is just visible at 467 feet elevation, then its contrast would have to be 0.65 at an elevation of 7000 feet for it to remain visible. At 1700 feet its contrast with the same limitations should be 0.87.

Thread Rolling. F. D. JONES. (*Machinery*, vol. 24, No. 8, p. 690, April, 1918.)—The rolling process of forming screw threads may be defined as an impression or displacement method, since the thread grooves are not cut by an edged tool, but are formed by means of a die or roll having threads or ridges which are forced into the metal and, by displacing it, produce a thread corresponding to the required shape and pitch. The plain blanks upon which threads are to be rolled are somewhat smaller in diameter than the finished thread, because when a thread is rolled a certain amount of metal is displaced and is forced up above the original surface of the blank, thus producing a screw thread which is larger in diameter than the original blank. The increase in diameter is approximately equal to the depth of one thread. No material whatever is removed by the rolling process, the metal from the depression formed by the die simply being forced up on each side.

Screw threads may be rolled (1) by using a circular disk or roll having a threaded periphery, or (2) by rolling the blank between dies which may be either flat or circular in form. The circular roll is employed when screw threads are rolled on automatic screw machines or turret lathes, and the dies referred to are used when thread rolling is done by means of machines designed exclusively for this work. Thread rolling is done in automatic screw machines when a thread is required behind a shoulder or other intervening part, which makes it impossible to cut it by using a regular thread-cutting die. The advantage of rolling the thread in such cases is that a second operation is avoided. The important commercial application of the thread-rolling process is found in the shops and factories using machines designed especially for this work. These machines are extensively employed in certain lines of manufacture for threading such parts as bolts, screws, studs, rods, etc., especially where such threaded parts are required in large quantities. Screw threads that are within the range of the rolling process may be produced more rapidly by this method than in any other way, which accounts for the use of thread-rolling machines in connection with bolt and screw manufacture and wherever thousands of duplicate threaded parts are required.

Waterproofing Drawings and Tracings Without Crimping. J. S. CARPENTER. (*Engineering News-Record*, vol. 81, No. 13, p. 597, September 26, 1918).—Waterproofing of drawings and tracings so that they can be used in wet places, as in mines, is done by the use of a preparation composed of rubber and benzol. The solution in less dilute form also makes a paste which may be used to join tracings and maps without the crimping of the joint that commonly occurs when water pastes are used. The pure gum rubber which is required for this waterproof paste can be bought at wholesale drug houses; the benzol can be obtained at most paint stores. The benzol-rubber solution will keep in any climate and under any conditions. As benzol is inflammable, it should be kept in a safe place in a covered jar. If proper precautions are taken in its use, however, it is no more dangerous than kerosene.

A convenient quantity of the solution may be made by adding a piece of rubber about 4 inches square to a half pint of benzol in a quart jar. The rubber will soon swell to three or four times its former bulk and will be ready for use in 24 hours. To prepare for use, pour about half the above quantity in another jar for thinning down. If drawings are to be coated, use a rather thin solution that will spread well under a brush. The drawing should be coated on both sides. For use as an adhesive, the solution should be fairly stiff, so that if it is desirable afterward to separate the joined parts, it can be done more readily than if a thin paste is used. There are cases where large tracings and blueprints must be made up of smaller sections, and for this work the paste is invaluable, as the joints will not be crimped out of shape and alignment. An additional use for the preparation was suggested when some of this solution was spilled accidentally on a dirty drawing. When the benzol was mopped up with a rag, the rubber was rolled up into a ball and the drawing was effectually cleaned by the operation.

Rubber bands instead of pure gum were tried, but it was found that they would not dissolve; they merely swelled up to many times their former size. Formaldehyde also was tried as a solvent, but its objectionable odor and certain other characteristics have proved it to be undesirable. When diluted as above directed the pure gum paste will not be costly.

THE FRANKLIN INSTITUTE.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard University
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N.R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., 1st Lieut.	Air Service, U. S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France

Name and rank	Branch of service	Location
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Washington
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington

Name and rank	Branch of service	Location
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase. Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.

Name	Appointment	Location
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Wahington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia

Name	Appointment	Location
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 2, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 2, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2724.—Rolin Patent Adjustable and Interchangeable Grate.

GEO. A. HOADLEY,
Acting Secretary.

LIBRARY NOTES.

PURCHASES.

FERRY, E. S.—Practical Pyrometry; the Theory, Calibration and use of Instruments for the Measurement of High Temperatures. 1917.

FRANKE, G.—Handbook of Briquetting. Vol. 2. 1918.
HAZEN, A.—Meter Rates for Water Works. 1918.
LAKE, S.—The Submarine in War and Peace; Its Developments and Its Possibilities. 1918.
MACELWEE, R. S.—Ports and Terminal Facilities. 1918.
North Carolina Geological Survey, Vol. 1, 1905. Vol. 2, 1907.
SIBLEY, R., and DELANEY, C. H.—Elements of Fuel Oil and Steam Engineering. 1918.
West Virginia Geological Survey.—County Reports and Maps. Barbour and Upshur Counties. 2 Vols. 1918.

BOOK NOTICES.

THE ZINC INDUSTRY: By Ernest A. Smith. London. Longmans, Green and Company, 1918, 211 pages, contents, bibliography and index, illustrations. 8vo. Price, $3.50.

This is one of the excellent series of monographs on industrial chemistry, several of which have already been noted in this JOURNAL. The present volume fully equals those that have already appeared. Beginning with an account of the position of zinc in industry, a brief notice is given of the history of the metallurgy, after which chapters follow devoted to the purely practical side of the subject. These are: Rise and Progress of the Production of Zinc, Zinc Ores and Sources of Supply, Marketing, Furnace Production, Other Methods of Production, Properties of Zinc, Marketing and Industrial Applications of it and its Alloys, Commercial Products, including Zinc Pigments. The text of the work closes with a chapter on the future of the zinc industry in Great Britain and a bibliography.

The work is a valuable and useful contribution to the literature of an important phase of metallurgy. Aside from this, the following quotations from the Introduction will prove interesting to the American reader: "Before the war, the world's markets for the majority of non-ferrous metals were very largely controlled by a group of German metal companies, engaged primarily in buying metals and acting as selling agents for the producers. How complete this control was few people knew * * * * The most important of these concerns was the Metallgesellschaft of Frankfort-a-M. * * * * This control was a source of great embarrassment to the British Government at the outbreak of the war." With a view of preventing such control in the future, the British Parliament passed "The Non-Ferrous Metals bill," designed to keep the control of the essential metals in British hands. Before the war the bulk of the zinc used in England was obtained from Germany and Belgium. Both countries were large producers of the metal, and large importers of ore from the most important mine in the British Empire, that at Broken Hill, Australia. The outbreak of the war led to a remarkable situation in British and Colonial markets, owing to the cutting off of supplies of the metal, and the loss to Australia of nearly all its markets for zinc concentrates. While there were enormous quantities of zinc ore awaiting shipment in New South Wales, most British smelters were unable to treat it, as their furnaces were not adapted to that class of ore. This shortage was partly met by importations from the United States, but notwithstanding this, the price rose enormously.

It is partly with a view of rendering England independent of Germany in the matter of zinc production that this work has been prepared. We wish it success.

HENRY LEFFMANN.

TNT. TRINITROTOLUENES AND MONO- AND DINITROTOLUENES: THEIR MANUFACTURE AND PROPERTIES. By G. Carlton Smith, B.S. New York. D. Van Nostrand Company, 1918. 123 pages, contents and index, 12mo. Price, $2 net.

The symmetric trinitrotoluene has become the chief explosive in war. It owes this position to its high shattering power. comparative safety, and as compared with picric acid—its nearest derivative—freedom from action on metals. Picric acid, containing a molecule of hydroxyl, readily ionizes with the production of an acid ion, which in addition to the corrosion that it may cause, produces metallic picrates that easily explode by friction or percussion, so that in time the acid becomes very unsafe. Six trinitrotoluenes can be obtained, but the processes now employed give almost entirely the symmetric (1-2-4-6) form, which is the only one now used.

The present work is devoted for the most part—as might be expected—to the chemistry and properties of the important form, though much information is given as to the accessory products. Beginning with a brief introduction and history of toluene and its nitro-derivatives, the theoretical principles relating to the nitrotoluenes are explained, after which the manufacture and purification of TNT are described. The inspection and testing are described, and also the properties of the series of trinitro-derivatives and of the mono- and dinitro forms. Two interesting chapters are those on accidents and diseases due to the manufacture of these substances. A very large proportion of the disagreeable features of such manufacture is due to carelessness of workers. Without doubt, illicit smoking has caused many disastrous explosions, and uncleanliness many cases of disease.

The work is a useful and concise account of the character and manufacture of a most important war-product.

The canons of criticism will not be observed if attention is not called to some blemishes. The literary style is often far from commendable, and typographic errors are quite numerous. The bibliography, especially, shows very careless proofreading. The misspelling "Anallen" occurs eleven times, "Jahres Berichte" (for "Jahresbericht") twice, "Proc. K. Accad. Metensch" (for "Ver. K. Ak. Wetensch") twice. Four allusions are made to the "London Chemical Society." If there is such a society—which the reviewer doubts—it is not the one intended, but the famous British organization, which is simply the "Chemical Society," without indication of locality or nationality. The reference "1st Scienze Let." will puzzle many. The publication intended is "Memorie del R. Istituto Lombardo di Scienze e Lettere" and should be abbreviated "Mem. Ist Lomb."

The bibliography appears to be in some confusion. Seventeen numbered references are given in Chapter vii, but only eleven are entered in the bibliography list for that chapter. When bibliographic references are made in a list at the end of the work—which is probably the best way—they should be numbered consecutively and not by chapters.

The book is timely, contains much information for the practical worker, and will be likely to find a rapid sale. When a new edition is called for, care should be taken to remedy the errors in grammar and spelling, avoiding such phrases as "The color of the solutions are different" and such misspellings as "assymetry." For the errors here enumerated, and for many others of similar types, the publisher must share responsibility with the author.

HENRY LEFFMANN.

CHEMICAL COMBINATION AMONG METALS. By Michele Giua and Clara Giua-Lollini, translated by Gilbert Wooding Robinson. Philadelphia, P. Blakiston's Son and Company, 1918. 332 pages, contents, indexes and bibliographies, 206 illustrations. 8vo. Price, $4.50 net.

The senior author is professor of general chemistry in the Royal University of Sassari; the junior author was awarded the Cagnola prize by the Royal Lombardy Institute of Science and Literature.

The work is a highly scientific and thorough discussion of alloys, especially of binary systems. The physical chemistry is explained, of course on the basis of the phase rule, and the conditions illustrated by numerous diagrams. The translator has done his work well, and the publisher and printer are also to be highly commended. The authors are to be praised for the care taken in the references to the literature of the subject, as year, volume and page are given. It should be an absolute rule in references to give the year. A list of publications cited, with the abbreviations used, is given. In this are to be noted a few typographic errors, such as "Liebigs" (instead of "Liebig's"), "Deutsche-Reiche-Patent," "Werhandlungen," "Compts rendus," but these are not misleading.

A summary of the chapter-headings will give an idea of the scope of the work: Equilibrium Diagrams; Thermal Analysis; The Nature of Intermetallic Compounds; Physical Properties; Homopolar Intermetallic Compounds; Heteropolar Intermetallic Compounds; Ternary Intermetallic Compounds. A series of tables and indexes of authors and binary compounds close the book. There is no index of the subject-matter in detail. The chapter on "Heteropolar Intermetallic Compounds" is a discussion of the compounds formed between what are commonly called "metals" and the elements often called "metalloids"; that is, carbon, silicon, boron, phosphorus, arsenic, sulphur, selenium and tellurium. The compounds of antimony and bismuth are treated under the "homopolar" section. It is rather startling to the gray-haired chemist to find calcium silicide and cuprous sulphide described in a work on alloys.

The book is a valuable contribution to the literature of metallurgy.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Airplane Characteristics: A systematic introduction for flyer and student and for all who are interested in aviation, by Frederick Bedell, Ph. D., professor in physics, Cornell University. 123 pages, illustrations, 8vo. First edition. Ithaca, N. Y., Taylor and Company, 1918. Price, $1.60 net.

U. S. Bureau of Mines: Bulletin 127. Gold dredging in the United States, by Charles Janin. 226 pages, illustrations, plates, 8vo. Technical paper 195. The tars distilled from bituminous coal in hand-fired furnaces, by S. H. Katz. 20 pages, illustrations, plates, 8vo. Technical paper 205. Saving coal in boiler plants, by Henry Kreisinger. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

American Glass Trade Directory of Glass Companies in the United States and Canada: Compiled by H. W. Gauding, of *The Glassworker.* Vest-pocket edition. 90 pages, 24mo. Pittsburgh, Pa., Commoner Publishing Company, 1918. Price, $2.

Trade Directory, containing list of pottery, glass, lamp, enamel and aluminum ware companies, also manufacturers' and workers' organizations: Compiled by Henry W. Gauding. Vest-pocket edition. 74 pages, 24mo. Pittsburgh, Pa., China, Glass and Lamps, 1918.

U. S. Tariff Commission: Tariff information, series No. 6. Census of dyes and coal-tar chemicals, 1917. 73 pages, 8vo. Washington, Government Printing Office, 1918.

New Treatment for Sulphur. ANON. (*Engineering and Mining Journal,* vol. 106, no. 15, p. 657, October 12, 1918.)—Recovery of native sulphur from rock mixtures with which it occurs in several Western regions is one of the problems calling for solution because of the increased war demand for sulphur and the consequent attempts to operate deposits of native sulphur in West Texas, Idaho, Wyoming, and Nevada. The liquation method, which has been practiced solely heretofore, involves relatively costly installations; the operation is expensive under the usually prevailing fuel conditions, and the recovery of sulphur has been low. Liquation plants have been operated in Wyoming and Nevada, and recently two were installed in the West Texas sulphur district.

About a year ago the engineers for Minerals Separation Company made tests for the purpose of demonstrating that the flotation method was applicable to the separation of native sulphur, and at about the same time Kirby Thomas, of New York, conducted a series of experiments which indicated that the recovery of sulphur by flotation methods was commercially feasible and presented advantages over the liquation operation. The data were subsequently presented to the Bureau of Mines, at Washington, and the Bureau arranged with James A. Hyde, of San Francisco, to make a complete and adequate series of tests. This work is now being done, and the results are reported to be satisfactory. The flotation process permits of the treatment of fines and of sulphur-bearing material not adaptable to the liquation method. The West Texas Sulphur Company, of Culbertson County, Texas, is planning to install flotation equipment as soon as the results of the Government tests are made available.

CURRENT TOPICS.

Adapting 220-volt Circuits to 110-volt Lamps. J. R. Calville. (*Electrical World*, vol. 70, No. 25, p. 1189, December 22, 1917.)—It is a matter of common knowledge that incandescent lamps which are rated at 110 volts or 125 volts are more satisfactory that those designed for 220 volts or 250 volts. Lamps designed for the lower-voltage range are more efficient, give a more satisfactory life performance, and are lower in price than the higher-voltage units, for the reason that the higher voltages are nearer the upper limit at which it is possible to manufacture incandescent lamps that will be commercially satisfactory. Notwithstanding these facts and that there are simple expedients, such as the installation of a balancer coil or a motor-generator set, whereby most installation using 220- to 250-volt circuits can be changed over so as to use 110- to 125-volt lamps, there are still many of the higher voltage in use. The difference in cost between lamps of the 110- to 125-volt class and those of the 220- to 250-volt class ranges from about 4 cents per lamp for the smaller lamps when purchased on large contracts to as much as $1.40 when the largest lamps are purchased at list price. The higher-voltage lamps also give only about 90 per cent. of the light which corresponding sizes of the lower-voltage lamps give. Hence, for equal illumination intensities more voltage is required with the 220- to 250-volt lamps.

In the design of new installations the number of units which may be used advantageously is sometimes closely limited by the constructional features of the building. In such cases, 220- to 250-volt lamps of higher wattage, and frequently the purchase of more expensive reflector equipment, are required. On the other hand, if considerable latitude in the location of the units is afforded, a greater number of the higher-voltage lamps of a given wattage will have to be installed to obtain the same degree of illumination as might be obtained with the 110- to 125-volt lamps. This will entail the installation of more outlets, the purchase of a greater number of reflectors, sockets, etc., and a heavier maintenance expense. The difference in cost of lamps of the two voltages, together with the fact that fewer 110- to 125-volt units are required—that is, the difference in first cost of the installation—is often of sufficient magnitude to pay for the installation of equipment to provide the lower voltage for the lighting circuit. The yearly saving in lamp renewals and energy is then pure profit.

The Magnetic Permeability of Steel. F. P. Fahy. (*Chemical and Metallurgical Engineering*, vol. 19, No. 5, September 1, 1918.)—The information to be derived from the normal induction and hysteresis data is of the first importance in the selection of material intended for use in the construction of electric machinery or apparatus which depends for its efficient operation upon the magnetic characteristics of some component part. Sometimes material of high permeability and low hysteresis is required, as in generators, motors and transformers. On the other hand, permanent magnet material must have opposite characteristics.

The question of the magnetic characteristics of iron and steel, and necessarily the methods of measuring such characteristics, is one of importance to metallurgists and chemists. The signal improvement in recent years in the magnetic quality of transformer steels is the happy result of skilled chemical and metallurgical treatment. The more recent work of Yensen on electrolytic iron melted in vacuo, when translated into practice will mean greatly increased operating efficiency in many forms of electrical apparatus. The magnetic characteristics of this exceptional material may be modified by variations in chemical content so as to adapt the material to special operating conditions.

At the present time particular attention is being given to research work on permanent magnet material. There are several reasons for this. First and foremost is the enormously increased demand for magnet steels. Again, a short time ago, the scarcity and price of tungsten led to further investigation in the matter of substituting chromium as the preponderating alloying element. Chrome magnet steels were not unknown, but the action of tungsten being apparently more favorable to the attainment of the desired magnetic characteristics, the use of such steels was limited. While magnet steels of good characteristics are readily procurable to-day, it is a fact that development in this direction has lagged to such a degree that there is opportunity for very considerable improvement.

Material intended for permanent magnet steels is practically always used in the heat-treated condition. Sometimes the steel after hardening is subjected to thermal or jarring aging processes. The residual induction when the magnetizing force is removed, and the coercive force or magnetization required to reduce the induction to zero, both should be as high as possible in value for a material intended for use in permanent magnets. Coercive force, besides being of value in overcoming demagnetizing influence, is also of assistance in counteracting the effects of severe vibrations to which magnets are frequently subjected.

While standard tests of permanent magnet material are made under conditions where the magnetic circuit is closed upon itself, corrections being made for its influence of joints in the circuit, magnets themselves are usually employed under circumstances where the magnetic circuit is open. An instance may be found in the case of a magneto. Here the circuit is made up of the magnet, two air-gaps and the armature core. The open circuit modifies in an important manner the induction designated as residual induction for the reason that the poles of the magnet exert a demagnetizing influence on the magnet itself which reduces the induction. A new term, namely, remanent induction, must be considered. Remanent induction is to the open magnetic circuit what residual induction is to the closed magnetic circuit. It is the remanent induction which determines the strength of the magnet under the conditions in which it is to be used.

The practical usefulness of magnetic data has been greatly augmented by the proof that they furnish valuable information as to the mechanical properties and structural characteristics of those materials which are magnetic in character, as iron and steel. The limitations of the microscope and the fact that hardness and chemical tests frequently fail to distinguish between materials, while the magnetic test shows distinct differences, greatly augments the serviceability of this new addition to metallurgical test procedure. Comparatively great magnetic changes accompany thermal or mechanical treatment.

The Oxide Film Lightning Arrester. C. P. STEINMETZ. (*General Electric Review,* vol. 21, No. 9, September, 1918.)—The practical experience of the last ten years has proven the aluminum cell arrester the only type capable of affording protection in modern high-power circuits. It has proven this so conclusively as to lead to its universal adoption in such circuits, despite the inconveniences incident to the need of daily attention in charging, the use of a liquid electrolyte, and the difficulty of testing the arrester without taking it apart, except by watching the appearance of the charging arc or measuring the charging current.

The oxide film lightning arrester represents a new type of lightning arrester which has all the characteristics and advantages of the aluminum cell arrester but does not require any charging, and thus requires no special attention. It contains no liquid electrolyte, no inflammable material, and like the aluminum cell arrester can be located out-doors as well as in-doors.

The cell of the oxide film arrester consists of two circular metal plates as electrodes, which are kept apart by a porcelain ring. The space between the electrodes inside of the porcelain ring is filled with the active material, lead peroxide, $Pb\ O_2$, which is packed in under moderate pressure. This active material is a good conductor, but has the characteristic that the action of an electric discharge converts it, in the path of the discharge, into a lower oxide which is an insulator. Thus when an alternating current is passed through such a cell, the active material at the electrodes gradually converts into a non-conductor, and forms a thin insulating film at the electrode. This grows in thickness until it cuts off the further flow of current and holds back the voltage, about 250 to 300 volts per cell. Then only a small leakage current of a few milliamperes passes at normal voltage, but if an over-voltage of any kind appears at the cell, the insulating film of lead oxide punctures and freely discharges through the lead peroxide in the path of the discharge into the lower non-conducting oxide, and closes the puncture holes, repairs or reseals the film.

A number of such cells, depending on the voltage of the circuit, are piled up on top of each other with a spark-gap in series. The need of this spark-gap in series with the arrester is the only still remaining undesirable feature which the oxide film arrester shares with the aluminum cell arrester, the multi-gap arrester, and other types.

Tall Chimneys in Metallurgical Plants. ANON. (*Engineering and Mining Journal*, vol. 106, No. 4, p. 168, July 27, 1918).—Tall chimneys are erected to achieve a definite result and not, as is sometimes thought, to satisfy a whim to produce spectacular effect. Apart from producing the necessary draft for the satisfactory burning of fuel, a chimney has two main functions: it removes and disseminates the waste products of combustion at a sufficient height to obviate or minimize danger or discomfort to individuals, or damage to crops.

The tallest stack in existence is that of the Tacoma Smelting Company at Tacoma, Washington, which was placed in operation in the beginning of March, 1918. The shell is built of paving brick on a concrete footing. It is 572 feet, 10 inches high, and 23 feet, 11 inches inside diameter at the top, and 38 feet 11 inches inside the lining at the base; the outside diameter of the stack shell at the base is 50 feet, 2 inches. The brick shell ranges in thickness from 5 feet, 1 inch at the base to 13½ inches just below the bell at the top. The stack has a 4-inch sectional firebrick lining, separated from the shell by a 2-inch air space.

The record for height was previously held by the reinforced-concrete chimney at Saganoseki, Japan, for the copper smeltery; it is still the highest reinforced-concrete chimney. According to the builders, the Weber Chimney Company, the Japanese stack is 570 feet high, 42 feet, 8 inches outside diameter at the base, and 26 feet, 3 inches inside diameter at the top.

Among other high chimneys may be mentioned those of the Anaconda Mining Company at Anaconda, Montana, 525 feet high and 60 feet in diameter; and at Great Falls, Montana, 506 feet high and 50 feet in diameter. These are of perforated radial brick, built by the Alphons Custodis Chimney Construction Company.

Abrasives. FRANK J. KATZ (*U. S. Geological Survey*).—*Emery and Corundum.*—During the first half of 1918 emery ore was produced by seven operators in the Peekskill district, in New York, and by one in southern Virginia. Corundum is produced from one mine in Macon County, N. C., and by one company operating in Renfrew County, Ontario. The combined mine output of emery and corundum in the United States and Canada from January 1 to June 30, 1918, was 5455 short tons. During the same period the producers sold, shipped, or used in the manufacture of abrasive articles approximately 4500 short tons, and the stock on hand at the mines June

30 was about 1500 short tons. As compared with the same period in 1917, there was a large decrease in the quantity of emery mined, and the output from January to June, 1918, inclusive, was considerably less than half of the mine output of emery for the entire year 1917. During the first half of 1918 corundum was produced at about the same rate as in 1917.

Artificial Abrasives.—Artificial carbide abrasives, including carborundum, crystolon, and carbolon, were produced during the first half of the year 1918 by two companies in the United States, operating plants at Niagara Falls, N. Y., and at Blasdell, N. Y., and by three in Canada, operating plants at Shawinigan Falls, Quebec, and at Chippewa and Thorold, Ontario. The plant output of crude carbide abrasives was 6583 short tons. During the same period the producers sold or used in the manufacture of abrasive materials 5633 tons, and on June 30 there remained in their hands as stocks 2840 tons.

Aluminum, oxide abrasives, including alundum, aloxite, exolon, lionite, and natite, were manufactured in the United States by four companies, three of which operated plants at Niagara Falls, N. Y., and one at Blasdell, N. Y., and in Canada by five companies, which operated plants at Niagara Falls, Chippewa, and Thorold, and two at Hamilton, Ontario. The combined output of these plants in the first half of 1918 was 28,341 short tons. During the same period the producers sold or used in the manufacture of abrasive materials 28,161 short tons, and on June 30 there remained in their hands 26,221 short tons. The combined figures for carbide and alumina abrasives for the first half of 1918 are: Manufactured, 34,974 short tons; material sold or used, 33,794 short tons; and stock in hands of producers June 30, 29,061 short tons. As compared with the first half of 1917, there was an increase in production of nearly 60 per cent. The production in the first half of 1918 was approximately equal to 62 per cent of that for the whole year 1917.

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THE RELATION OF PUBLIC SERVICE COMMISSIONS TO THE GAS CONSUMING PUBLIC AND TO THE GAS COMPANIES.*

BY
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President of the Institute.

I UNDERSTAND that I am asked to try to give to you who are concerned, or who may become concerned, in the administration of governmental bureaus provided to secure the development of the gas industry and the regulation of gas companies, the ideas that the gas industry holds of the obligations of such bureaus to the public and to the gas companies, and of the proper methods of procedure in such regulation and development. While I fully believe that what I have to say expresses the general opinion of the American gas industry, I want you to know that I am not delegated by the industry, or by any gas company, to speak for it in this matter.

The limit of time placed upon me in the invitation to address you, and which I shall but slightly exceed, indicates that I am expected to confine myself to a very general discussion of our subject. I regret this limitation because it cuts from proper consideration many important mooted questions, among others of perhaps only less importance, methods of valuation and of charging, of determining upon what amount of investment the owner is entitled to earn a profit, and of so arranging schedules

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that each customer shall contribute his proper share of the cost of maintaining the gas service.

I ask you to have in mind as I talk to you that I am a layman and speaking the language of a layman to a body of lawyers. I shall tell you the story that I bring as I would tell it to any body of men of a profession other than my own, without an effort to make it other than a plain tale and without thought as to how differently it may appeal to the legal mind than to the lay mind.

I have no list of decisions or citations. The purpose I have in mind is not to enquire what courts and commissions *have* established as to the relations between public and public service corporations—gas companies in particular—but to consider what courts and commissions reasonably may be expected to establish in the intelligent performance of their duties—what they must establish to meet the obligations they have accepted, namely, to secure to the public good gas service at a reasonable price, and to the investor the profit that will be a fair return upon his investment and will hold him, and, as becomes necessary, induce others to the investment.

Also I ask you to remember that we of the public service industries—owners and employees—are American citizens, having the same interest in the establishment and maintenance of correct principles of government, and the wise performance of all governmental functions, as have all other American citizens; and that we necessarily look at the problems we are to discuss to-day not only from the view-point of the operator of a public utility seeking opportunity to perform his function creditably, and usefully, and of the investor in such a utility seeking to protect his investment, but also from the view-point of the citizen seeking to establish and maintain the best ideals and forms of government and in every way possible to strengthen the social fabric.

There are conveniences, comforts and protections of urban life possible to combined effort, impossible to individual effort. Such of these as confer benefits impossible of accurate measurement and of apportionment of cost in proportion to benefits received, or as are of equal benefit to each citizen—each citizen's proper use being of immediate interest to all citizens because of the direct influence on the general health and order, such conveniences, comforts and protections are ordinarily at the general expense and paid for in taxes. Such are police and fire protection, sewage facilities and the administration of justice. Other such conveniences, comforts and protections, impossible of individual provision, conferring benefits that are susceptible of accurate apportionment of cost, and utilized by the citizen if and when he will, and in quantity as he desires, and as are substantially without the factor of general benefit from individual use, are ordinarily provided at a price per unit of service rendered. Such are the gas supply, the electricity supply and the street car service.

There is no question of the importance of each of these agencies of civilization or of the duty of government to secure their benefits to the citizen. On this point, Mr. Walter L. Fisher, recently Secretary of the Interior, closes his essay, "The American Municipality," with these words: "What must be recognized is that the city cannot escape its primary obligation so to develop and control its public utilities, whether in public or in private hands, that they shall be effective instruments for the service of the individual citizen and the development of the organized community."

The development and control of public utilities being a function of the state, and the state having power to delegate its functions, this function of development and control may be performed directly by the state or by such delegate, whether company, municipality, commission or other, as the state may select or create for the purpose.

Since Mr. Fisher wrote his essay in 1906, the legislatures of the majority of the states of the Union have delegated this duty and authority to so-called Public Utility Commissions. The power of decision in matters of price of gas, quality of gas, character of service, raising of capital, issuance of securities, etc., so far as theretofore a function of gas companies generally, has been taken from them and lodged in state commissions. With this shift in power from company to commission necessarily has occurred a corresponding shift in responsibility.

Such state created commissions are now in existence in about forty states and territories. The group of states having commissions charged with full or with some lesser measure of control of gas companies, and with responsibility for the protection and extension of the gas industry, now includes all of the larger states and contains about eighty per cent. of the total population of the Union. Therefore, the condition which Mr. Fisher declares to be an unescapable municipal obligation to secure, must now be secured through the action or with the consent of a state public utilities commission in most of the states of the Union.

It is profitless to discuss the necessity to the public good for the formation of state commissions to develop and regulate gas companies, as it is to study the causes of the public agitation resulting in commission legislation. Commissions are a fact, and the gas industry generally will admit that where operated with intelligent good intent they will afford a solution of the difficulties ever existent where a corporation has a monopoly of the supply of a necessity. We of the gas industry do this without abatement of our claim that in the past we have properly ordered our affairs and have been in the best sense public servants. Our past is our convincing witness.

We gas men, by our experiments, by our searching of the laws of nature, by our canvassing, by our insistence and persistence in getting consumers to use appliances that would be useful to them and save them money, have so extended the sale and reduced the cost of gas, while greatly improving the quality, that we have been enabled to reduce the price per unit to 40 per cent. or less of what it was a generation ago. This is truly public service, and to the result there is no parallel in the history of industry. We are no factor in the high cost of living. In the algebraic sum that represents the increase in the cost of living, we are a negative quantity. In no other line of industry will you find such a history; such a record. I say it, seriously, confidently and with pride. And it has come through conscientious work and the adventurous investment of enormous sums of stockholders' money. We do not assert an altruistic motive, but we believe that our accomplishment to the public good justifies our claim that we are in the best sense public servants.

The business of the manufacture and supply of illuminating gas is about one century old. From the beginning it has been an important factor in community life. This importance has enormously increased during the last quarter of a century. To-day, no factor more important enters into the life of the urban population—except perhaps such as have to do directly with the health and peace of the community; and on these a well ordered street lighting system has a highly beneficial influence.

In the earlier years of the industry's life the use of gas was almost exclusively for the production of light. "Candle power" was its most important quality. The industry's development has been coincident with that enormous extension of knowledge of physical science which has marked the last century. It has kept pace in growth and development toward scientific perfection with the general industrial movement of the century. And this development has brought gas very largely into fields of usefulness where its heating power is its most valuable characteristic. It has become, decade by decade, more important to the prosperity of communities. Since the beginning of this century, and mainly through the convenience and cheapness of gas as a heating agent, the industry has increased in importance as a social factor in measure greater probably than has any other industry. This largely has come through the introduction of gas for cooking and water heating to city kitchens and particularly to the kitchens of people whose related women folk do the family cooking. A little thought will convince you that the 360,000 gas equipped kitchens now in the city in which I am writing must represent the release of a host of women from a large measure of the drudgery of their lives. But unless you have had definite information on the subject you probably do not realize how great is the saving of time and labor. Careful observation justifies the statement that the use of gas for cooking and water heating saves an average of about one hour a day of the time of one woman or girl cook in each of 360,000 homes. One hour a day release from the duties of fire building, coal carrying, ash removing and the consequent cleaning of vessels, implements and surroundings; and one hour per cook per day is over eighty years of twelve hour days—eighty years of twelve hour days of woman's disagreeable labor saved each day in one city by the use of gas heated domestic appliances! Statesmen and economists must recognize this as certainly a factor of the highest importance, and as marking the continuance and extension of the industry as essential to the maintenance and development of the best condition of urban life. And in this time of stress, with need in war work for every available hour and unit of energy, this eighty years of woman's hard and disagreeable labor economized per day in one city is an enormously valuable asset to the nation.

With the war the gas industry has become the principal source of some of the most important raw materials of explosives. About 30 per cent. of the hydrocarbon bases of the explosives now being used by us and our allies are coming from gas manufacturing plants. Thus in war the industry contributes one of the necessities of the nation's protection, as at all times it supplies one of the comforts of modern domestic urban life. These two uses for gas with their beneficent influence on women's lives and on the security of the nation, and with the economy of the material resources of the nation which are incident to them, so clearly mark gas service as one of the necessities of modern life that I regard them as proving the claim expressed by Mr. Fisher that its development and control is one of the primary obligations of government. I feel it is not necessary to dwell upon the importance of gas as an illuminant in millions of homes and on thousands of miles of highways, and its wide and growing use as a labor and material economizing source of heat in scores of industries—many of them industries essential to the conduct of modern warfare.

This relation of the gas industry to the public good has come to full recognition in this country only within the last quarter of a century. The importance to the public welfare of insuring its efficiency and prosperity, and these at the lowest possible cost to the user of gas, is now no longer a matter of debate. The realization of this importance to the public welfare has found most recent expression in the formation of state commissions—whose functions we are now considering.

The political history of the gas industry shows that from its earliest days the general effort of governmental bodies has been to secure the establishment and maintenance of the industry—however unwise and ungenerous has sometimes been governmental treatment of gas supplies of apparent prosperity. The gas industry's political history is the story of governmental effort first to establish, next to regulate by unelastic provisions and competition, and finally, through commissions or so-called "sliding scale" agreements, intelligently to develop and regulate the business of gas supply.

The history of this governmental effort must be of interest to the student of public utilities in their relation to government and to people.

About the beginning of the nineteenth century certain philosophers and experimenters in Great Britain and France were brought by their studies and experiments to believe that it was possible to manufacture and to distribute to the inhabitants of cities a source of light and heat that would be always ready for use, require no storage on the premises of the user, be measured as used, and leave no ashes or other undesirable evidence of its presence and use. Some few men of financial means were among the believers. The realization of this belief, which Napoleon characterized as "Une grande folie," and Walter Scott called the "Dream of a mad man," came with the introduction of illuminating gas to London under a charter granted in 1812 in the name of George III, King of Great Britain.

While a few dreamers had had faith, the public had scoffed. Parliament, when finally brought to realize how great might be the importance to the community of such a service as the dreamers prophesied, was liberal in the terms given to the speculative investors. The charter granted the "Gas Light and Coke Company"—the first gas charter ever granted anywhere—imposed no restrictions except that the extent of the experiment, and therefore of the possible loss, was limited by limiting the amount of capital permitted to be raised. In the fixing of the price and quality and of conditions of supply the Company was left to the exercise of its own judgment and will. Regulation was impracticable from any point of view. Nobody knew, or could know, what it would cost to make gas, what the quality of the gas would be, nor even in what terms of comparison the quality would be expressed. Nor was it known what measure of competition the gas supply would find in candles and whale oil—the illuminants of that time. It was seen that a gas supply as forecast would be highly useful and it was known that it would have to commend itself in price and quality in order to make head against other sources of nocturnal illumination.

Also, it was known that great latitude must be allowed investors in an enterprise generally prophesied to be doomed to failure. Such investors must have the expectation of unusual profit if their enterprise prove serviceable to the public, to balance against the certainty of total loss if the general expectation of failure were realized.

The corporation was given power to experiment with quality and price. Whatever course seemed to offer the fairest prospect of profit, it was free to pursue. In view of the undeveloped state of the art involved, no other course could be expected to secure the establishment of the industry. No other course would give investors such hope of financial reward as to induce them to the precarious investment.

Briefly, the governmental purpose was the establishment of gas service if it were physically and commercially possible. It was a wise purpose, and they went the right way about it.

The earlier years of the enterprise were lean years, indeed. Apparatus was experimental and inadequate. There were no meters. The gas company sold gas at first by contract at a price per burner, called a "gas rental." The ease with which the supplier could be cheated invited cheating, and the quarrels over bills that arose from the lack of certain means of measuring the service rendered, made the gas business of those years an irritation, certainly, to all concerned, and probably a demoralization as well.

But in 1817 a small dividend was earned, and the success of the theretofore experimental enterprise appeared assured. Doubtless, the adventurous men who had provided the funds for the enterprise expected in peace to reap the financial reward for their sagacity, as probably already they were reaping in the respect of their fellow citizens a reward for their courageous public spirit. But trouble was brewing for them. Their success bred a desire in others, less courageous, to share the profits of the industry, at that time believed to be prospectively enormous.

The Parliament then perceived that the corporation, which had been invested with the right to occupy the sub-soil of the streets was enjoying therein what was and would continue a de facto monopoly as long as no further parliamentary action was had, and would likely prove highly successful in its business.

The importance of protecting the gas user from the results of wasteful management and inordinate profits was emphasized by a class of investors who sought to share in the profits of an industry they had not had the courage to initiate.

The benefits to flow to all interests, state, citizen and investor, from creating the gas industry a regulated monopoly and its capital a safe and profitable investment, were not realized, or were ignored.

The Parliament, being not less susceptible, perhaps, than are Parliaments of our own time to the ever fearsome cry of blindness to the people's interest, hastened to give evidence of its interest in the quickest and most obvious way.

The obvious remedy for monopolistic evils being competition in kind, and the danger of unregulated monopoly being emphasized, without intelligent suggestion of the merit of established regulation, competition in kind was established. Competition ran its full course in London. Ten years after the formation of the first gas company there were four companies supplying that part of the city lying north of the Thames. Later there were thirteen gas companies with mains in the streets of London. In many streets there were three lines, and in some streets four lines of rival mains. This competition failed of its purpose. Rates were higher in London and service was poorer than in provincial cities, where the industry was a monopoly. Dividends, when existent at all, were small. Finally the nuisance to the public became intolerable, and in 1860 the Metropolis Gas Act, permitting a districting of the territory, was passed, and competition ended. This was soon followed by gradual amalgamation of the thirteen companies—mainly into two great corporations—one operating north of the Thames and one south of the Thames. From the date of the last amalgamation the political history of the London gas industry is the story of effort to encourage investment in gas shares (for extensions and improvements) and to maintain the least possible selling price for gas consistent therewith. This has been secured in London through the operation of the "Sliding Scale" and "Auction Clauses" established by Acts of Parliament.

I am not given enough time to discuss the various governmental experiments prior to the adoption of the sliding scale principle of control, nor to enter far into the detail of the operation of this admirable device. Briefly, the first purpose of the sliding scale was to encourage investment in the business at the lowest obtainable rates by taking advantage of the competition of the entire unemployed capital of the nation, while stimulating this competition by offering the stock issued for new capital at auction. The second purpose was to enlist the self interest of owners of gas shares in the effort to reduce rates for gas by providing that the dividends permitted to be distributed—if earned—should vary inversely as the selling price for gas was varied. This plan secured money for improvements at the lowest possible rates, and because of the security of the investment these have been very low. It protected the investor, and resulted in almost unbelievably low prices for gas. This for forty years. The war has temporarily unhinged the scheme, because the great increase in the cost of labor and materials compelled a cost and a selling price at which no dividends are possible under the sliding scale provisions. If the price per ton of gas coal (less credit for residuals) and the price per hour for common labor had been made factors in the formula for controlling the price, as might easily have been and as has been provided in part by an act of the Australian Federal Parliament, the sliding scale would have continued to do justice to public and corporation in this time of war, as during the last forty odd years of comparative peace.

All British gas companies, not operating under the sliding scale, have to go to Parliament for power to raise new capital, and therefore at irregular intervals come under governmental investigation and regulation.

This is briefly and broadly the political history of the gas industry in Great Britain in so far as that history has to do with the regulation and protection of gas companies, and the encouragement of extension of gas service. It is not necessary to my purpose to discuss the tendency to municipal purchases of gas undertakings, which was quite pronounced about twenty-five years ago, but has had little force for many years.

America, in the main, escaped the evils of competition in gas supply in the earlier years of the industry, but this was not through intelligent governmental efforts at regulation and protection, and it was at the cost of all the ills that come with the exercise of an unregulated de jure monopoly. Indifference on the part of the servants of the monopolistic corporation, neglect of effort to reduce cost of service so long as dividends were earned, on the part of the owners—irritation born of suspicion of all this on the part of the buyer, and, worst of all, suspicion, and angry, unreasoning charges of dishonest metering—of these is unregulated monopoly the fruitful mother. It is to the credit of the men who controlled the American gas industry through the monopolistic days that there was little justification for charges of indifference and inefficiency—as there never was any justification for charges of dishonest metering.

American cities found it generally necessary to the first enlistment of capital in the local establishment of the industry to grant monopolistic rights for limited period. Rarely, there was a quality provision in these early franchises. As these franchises expired they were renewed but generally without the monopolistic feature and generally with unelastic regulatory clauses of varying character included. The owners had necessarily to take practically what renewal terms were offered them, and some were taken with great misgiving. But the great growth in population of American cities and the greater growth in the sales of gas—mainly due to the intelligent persistence of gas companies to develop its use as fuel—has enabled these companies to maintain a measure of prosperity through a period of rising costs and of generally lowering income per unit of product.

About the year of 1880, the so-called Lowe Water Gas Process for making a superior quality of gas from anthracite coal or coke and the then otherwise valueless distillates of petroleum was invented and became the ground for the formation of many companies in competition with others already in the field. These competing companies have all been combined with their one time competitors. There was, at the time, a wastage of capital through the formation of these competing companies, but by the increase in use of gas, since realized, the apparatus, mains, etc., of the combined companies have become necessary to the service.

The above brief and rough sketch of the history of the gas industry shows, I think, that as a factor in the development of home comfort and street safety it has had some pretty crude treatment. Yet the gas companies generally have been able to earn dividends and the citizens have had good service. It has been a growing business, and, like a growing boy, has been able to survive the diseases and spankings of infancy and childhood.

The industry, and the company and governmental effort to make the industry "an effective instrument for the service of the individual citizen," have now a perspective. We may see the good accomplished, the mistakes made.

It is too late to prevent the ills consequent upon the early mistakes, but most of these mistakes have run their course and no longer hinder progress. We may learn somewhat from them. The effort of governing bodies, as directed toward gas undertakings, though often blundering, and sometimes vengeful, has generally had the right purpose—the purpose to secure and to continue, first, gas service; second, low-priced gas service, and finally high grade gas service, at as low cost to the user as possible. Through such encouragement as has been given the industry, it has been sought to secure a measure of relief, of easement of the labors of the people. More comfort, less labor, in the home and in the shop. More safety on the streets at night. More money on hand after bills have been paid. Wiser treatment would have resulted in more accomplishment. But the purpose at all periods, though not in all individual cases, has been the advancement of the general good. The methods too often have been harsh; almost uniformly, in this country, they have been rigid. But now we have in commission control an elastic medium, uniting the corporation and the public interest, and from such control we may, and do, expect continued development of the great industry and the best practicable service to the public at the lowest possible cost—long strides toward reaching the goal established by Mr. Fisher's pronouncement.

What must be done to insure the realization of this expectation—to insure that gas companies shall be and continue such "effective instruments" as Mr. Fisher defines—is our problem in so far as we have to do with public utility commissions, or with the operation of gas properties. Our answer has to do first with the provision of plant.

An adequate generating plant and a system of street mains that reaches the dwelling of every citizen within the limits of Mr. Fisher's "organized community" who desires gas service and is able and willing to pay the cost of rendering it to him, are essential parts of an "effective instrument for the service of the individual citizen," and "for the development of the community."

Since the first step toward effective gas service is the provision of a suitable and adequate plant, and since capital is necessary to such provision, gas companies must have means of raising capital as needed for extensions and improvements, or they will not be able to perform the functions which Mr. Fisher characterizes as a municipality's "primary obligation to secure."

And here we must realize the great shift of responsibility for the development of the industry that has come with the creation of public utility commissions.

When character of service and price of gas were under its own control, a gas company, accepting a franchise, accepted an obligation to provide and maintain a plant adequate to the demand for the service it supplied in the community it served. Its obligation was to be ready for the demand as it came, if reasonably foreseeable, and to get ready with dispatch for unforeseeable demands. The proper performance of these duties is a very serious matter. On it depends some measure of the welfare of millions of people—and the security of millions of invested savings of scores of thousands of people. Since the creation of public utility commissions, endowed with the sole power of control of rates and capitalization, the obligation of a gas company to be ready to supply gas to all in its territory willing to pay the cost of service is no longer unqualified. It is obvious that as the control of the character of service and price of gas have now been taken from the gas companies, the companies themselves cannot any longer create the conditions necessary to insure such profits as will invite capital to the enterprise. The obligation to provide a plant adequate to the demands that may be made upon it is now conditioned upon the opportunity being insured the company to earn and divide among its stockholders such profits as shall make its securities a desirable investment in a competitive money market. This opportunity is now dependent on commission action. It is now therefore the duty of a commission to determine and order that combination of character of service and price of gas which will be so prophetic of profits as to command the capital necessary to enable gas companies to meet the demands upon them. In the view of the gas industry, and in view of Mr. Fisher's pronouncement, this is the great significance of the change from company to commission control.

No man—present stockholder or other—is required or may be forced to provide the necessary capital; he must be persuaded. There is but one way to persuade him. It is to make the investment so attractive that capital will seek it. This is in the hands of the commission. The gas company has little to do with it beyond foreseeing the necessity and presenting its petitions and arguments to the commission. If the commission fails to order such price and conditions of service as will earn the dividends necessary to attract capital in a competitive money market, there will be no capital provided, and there will be no extension of service. There will be a shortage of a necessary service in the community, and the commission will have failed in its most important function. It remains the duty of gas companies to provide such service as is ordered with the least practicable expenditure of labor and material.

The timidity of capital has passed into proverb. In considering the course to be followed, to insure that capital will come to our undertaking, we must remember that men will not invest in an industry which is under a cloud, or with even a remote (if perceived) danger of entire or partial confiscation of property or of profits.

Industries are normally in competition for capital in the money markets of the world. Before capital will flow into a public utility, opportunity must be assured it to earn, without wastage of itself, at least such a measure of return as could be expected from any other use at the time offering. A gas company must have credit of this kind in the money markets of the world or it cannot secure the funds for the extensions that are necessary to maintain and extend the service as the demand for gas increases, and to realize economies as the art advances. A gas company can secure credit only through confidence in its future earning power. Since the most potent of the conditions essential to the earning power of the industry are under the commission's absolute control, the prospective investor, whose money is necessary to make and maintain the gas property as an "efficient instrument," will require before investing to know what the commission has done and is likely to do in the matter. If the investment appeals to him at all, the rate of interest that he will be willing to contemplate will bear some inverse proportion to the assurance of opportunity to earn the rate. Since the interest on the investment is a factor in the price of gas, the more secure the investment the lower the price of gas.

The combination of price and character of service established, must give promise of sufficient gross income to cover all operating expenses, to provide a sinking fund to restore all parts as they wear out and to retire any parts that become obsolete or inadequate (but, except in the case of limited term franchise companies, not to return any part of the investment to the investor), and leave enough net reasonably to insure ability to pay upon existing and proposed investment the rate of interest the money market at the moment demands from such investment. Failing this, there will be no new investment. This appears obvious.

If I appear to have unduly and with unnecessary iteration emphasized this thought, it is because I so realize that lack of ability to secure capital is the greatest danger to the ability of the gas industry to properly serve the public under commission regulation, and because I so much desire to persuade you that the first step toward what Mr. Fisher characterizes the unescapable "primary obligation" of the municipal government, now can be met only by the commission—and by it only through the establishment and maintenance of such a combination of quality and price as will make and keep the business attractive to free money in a competitive market.

Clearly it is to the interest of public and of investor to prevent any avoidable element of risk, or gambling chance, entering the investment. It is to the general interest—certainly to the public interest—that the investing public should have such confidence in the security of the investment as not to require the hope of abnormal profits to induce it to buy gas shares for extensions of service. This confidence will be strongest and rate of interest and price of gas lowest where previous investment has had protection.

It is impossible to determine universally applicable, or even generally applicable, standards of price, quality of product and character of service best to be established—that combination which will give to the consumer the greatest benefit per dollar paid. The materials of manufacture available for use so differ in kind and cost throughout the country that standards of quality and price best suited for one state or city may be impracticable for another state or city, and costs of operation will vary with the volume of the business. But there are certain general principles governing these and other matters under commission control and applicable to all situations. These should have mention, and I shall make such brief reference to them as my time permits.

Permanence of tenure should be assured to gas companies.

A company of limited life must provide from its earnings a fund to retire at the end of its life all investments made in its property less its prospective selling value, and this provision will correspondingly increase the cost of gas.[1]

The selfish interest of each gas company should be enlisted in the effort for low rates and good service. The public interest in this extends beyond the class of gas consumers—for a low selling price means a low cost, and a low cost means the conservation of the human and material resources of the nation.

In the general interest there should be the establishment of such standards of quality and service as will permit the widest selection of materials and methods of manufacture practicable for the locality and leave the broadest possible scope for the exercise of engineering skill. This will also tend to national conservation, as well as to reduction of costs.

Character of product and quality of service should be established under penalties sufficiently heavy to insure compliance and systems of inspection under competent men should be established adequate to the detection of violations of established regulations.

Established selling prices must be sufficient to permit such a margin of divisible profit as will insure further investment as needed in a competitive money market.

When a gas company seeks to raise new capital for additions or betterments to its plant, it should be compelled to show the necessity of the proposed expenditures and that each dollar of new investment made and securities issued will add a dollar of value to the property. Uniform systems of accounting and reporting should be adopted.

Further than these things regulation should not go. These things having been established, it should be left for the company to work out its own salvation, and it will be found to the general good to encourage hope in the gas man's breast and to permit special effort and special efficiency to reap a special reward, as under the "sliding scale." It is by leaving with the corporation officials all the latitude consistent with the enforcement of regulations as to standards and rates—all possible initiative—all possible hope of coincidentally serving stockholders and public—that the best and ablest men will be attracted to the service—and the lowest rates assured to the consumer.

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[1] Where the price of gas fixed has not yielded the surplus earnings necessary to the creation of a fund for the retirement of the investment in a plant operated under a limited franchise, the commission concerned must in justice and in the general interest, protect the owner from the loss that would follow if the municipality at the expiration of the franchise took advantage of the situation to acquire the property for less than its value, or to impose an unprofitable franchise extension on the company.

The per cent. of return necessary as an expectation to secure the investment of new dollars is the per cent. that for equity and for the accomplishment of purpose must be allowed to be earned on the entire value of the property devoted to the public use; that is, the value in dollars with which the new dollars by their investment are merged.

An industry's credit is dependent in large part on the record of its financial past—on what return, what per cent. of its value, it has been able and permitted to divide. This value then must have an important place in the commission's formula for the determination of the price to be charged for gas.

I wish I might discuss at length the various practiced and proposed methods of arriving at this value of existing properties as a step in the process of determining the cents per thousand cubic feet necessary to include in the price of gas for return on capital, but, though this is of the first importance, time forbids. It is of the first importance to the public because upon the justice of the determination will depend, on the one hand, the ability of the company concerned to raise money for extensions, and, on the other, the ability of consumers to obtain gas at the lowest possible cost.

Though I am not given the time adequately to discuss these various methods of valuation, some of the factors are so important and so far from general agreement that I think I must present them, though at the risk of out-wearing your patience.

After a commission has decided what rate per cent. of profit is necessary to do justice to present investment and to insure future investment, its next step will be the determination of the amount upon which this rate is to be earned. This step is generally called the "valuation" of the property, and it must be taken as one of the preliminaries to the final step—fixing the price.

No man may dogmatize on methods of valuation—there have been too many intelligent differences of opinion to permit that. I give my thoughts on the question with full recognition of this truth.

If the problem concerned a company starting all new, it would be simple. The commission would keep an account of the expenditures of money from whatever source derived, in construction, in the development of the business, or otherwise; of the value of the property acquired other than by purchase, if any; of all issuance of securities for service rendered or for property; and of the interest on each of these during the period of construction and during the period of development to the point of earning the predetermined rate of profit. The sum of these items, less such amount of interest as might be earned during the period of development, would be the value of the property upon which the predetermined rate of profit should be earned.

In the majority of instances of companies of many years' operation this amount of actual and properly to be capitalized investment cannot be determined from the books. Even if the books disclose all capitalized expenditures, they will fail to reveal great numbers of expenditures, some on other than construction account, many on the lesser betterments and extensions made from the funds of the companies, properly capital charges, but not capitalized on the books. Also there may have been expenditures not capital in character but capitalized on the books where loose systems of accounting have prevailed. So in the majority of cases that will come before commissions the properly capitalizable investment cannot be had from the books of account. Under these circumstances the most practicable way of determining the amount upon which the determined rate of interest shall be earned is by inventory and by valuation of inventory, part by part. We are able to inventory and thus to value the physical property within a very small per cent. of accuracy, and having this value for the physical property we may make additions thereto of other items that cost money or securities to provide and that add to the amount upon which interest must be earned, if investment in the property is to be attractive. Among these are working capital and going value, discussed below, banking charges, organization expenses etc., and interest on each item of cost during the period of development to the point of profitable operation. The sum of these items is not the value of the property as this value will be when the price of gas and the resultant earnings are known, but it is a figure upon which reasonably to base the estimate of earnings necessary to do justice to the present owner, and to make the business attract the savings of others. The real estate we may value at once by comparison with similar properties similarly located. The structures may be inventoried and their costs determined. I think that we can arrive at the cost of structures to the company in no way better than by determination of cost to build—if with physical conditions, such as pavement, rock, grading, etc., as they existed at the time of construction. And I believe that the average prices prevailing over a period of five years will come very near the average of the actual prices paid through the life of the property, as part by part it has been acquired or erected. This would certainly be very nearly true for any period of five years other than the immediate past, with its great advance in the cost of everything, and for which allowance must be made. I believe that this method of determining the figure for value of property in the formula whose solution is to give the price at which gas must be sold, will do justice to the consumer, to the present owner and will be satisfactory to the prospective investor. I do not know of any other method so promising.

There are instances in which franchises have a value for capitalization in the hands of their present owners. These are special cases, too various for general discussion.

I think it is important here to discuss briefly the oft-discussed questions of the effect on value of pavements and of accruing depreciation.

Some courts of high authority, in what I think a rather vague effort to find a basis for a guess at value, have made lists of various compositions of items—so-called "relevant facts"—to be given consideration, though not necessarily to control, in determining the value of the property devoted to the public use. In these lists is included as a factor to be considered the expenditures necessary to build the plant as existing at the time of valuation. This is called "replacement cost."

The existence of pavement on the streets adds materially to the otherwise cost of replacing mains and services. Where this "replacement cost" is used as one of the "relevant facts" to be given consideration, the cost of existing pavement must be included, if "replacement cost" is to have its full and proper influence with the other "relevant facts" on the final mental conception which the advocates of this method form of value. But, since pavements laid subsequent to the laying of mains now under them have added neither to the investment of the owner nor to life or capacity of the mains, I do not believe it is necessary to include the cost of such pavement in the amount upon which interest must be earned in order to do justice or to insure that confidence in the security of the investment which will result in futher investment, as needed. I hold this view though in some cases courts and commissions appear to have held otherwise. The added cost of operation, due to the existence of pavement with the necessity of occasionally cutting it for repairs to piping and the interest on the cost of mains laid in temporarily unprofitable territory to keep ahead of paving operations, must appear in the formula for determining the selling price of gas.

Another much-disputed question is whether a plant valuation should take into account the so-called, and unfortunately so-called "accrued depreciation." As I see it, a commission properly insisting upon a plant being kept in condition to render 100 per cent. service cannot consistently deduct from the value of the plant as if new, any sum for "accrued depreciation." I hold this view, though in some cases courts and commissions have held otherwise.

"Accrued depreciation" must not be presented as indicating a run down or deteriorated condition for efficiency or for service, for this would be to mislead. Rather it must be regarded as indicating an accruing and not yet matured obligation of the owner of the plant to renew the plant, part by part, when necessary to maintain its efficiency and service-rendering value.

The consuming public's account with the owner of a gas plant stands always properly chargeable with the cost of the plant as if new, because as time elapses between the date when the plant was new and the date it will become necessary to restore any part, the reduction in the period of its useful life, which will be occurring, is offset, coincidently and commensurately, by the accruing obligation of the owner to renew the part when its period of satisfactory service is past. He has this obligation accruing—and he has also, throughout the life of the plant, his full original investment. He cannot escape this obligation as maturing, which in a large plant for some one or more items of construction is a matter of almost daily occurrence, without impairing, and perhaps destroying, the utility and earning capacity of his entire plant. Nothing in the industry is more certain than the renewal of parts as they wear out. It may be that the owner has wisely set aside each year a certain part of his earnings against the date of renewal of the larger structures. But whether or not he has foreseen and provided for the time of renewal, it will come, and almost daily as it does come, he has to provide the cost from other sources than additional capitalization. Therefore, if we deny to the owner the opportunity to earn interest on the full reproduction value of his plant, that is, its cost if new—his investment—we compel him to devote a part of his investment to the public use without compensation, and we insure that he and they who know of his experience will avoid thereafter any similar investment. He has through the years an investment equal to the reproduction cost of the plant. Through the years he gives to the public a service not inferior to that rendered by a plant entirely new; for the signal for renewal of a part is the immediately prospective inadequacy of the part to continue to give good service. To renew any part while it is still capable of giving good service would be a waste of money and involve an added cost to the consumer. Before making any further investment the owner will require assurance that his earnings through the years will be upon the full amount invested. In return the service given will be as if from a new plant in all other respects similar.

The cost of current maintenance of the plant—of restoring parts as they wear out—is necessarily an operating charge and will appear in the cost of the gas. I believe that all courts and commissions that have considered this question agree in this.

In addition to the physical structures are certain items of cost of establishing an operating gas company properly to be capitalized and return a profit. Among them are working capital—a very tangible thing—and "going value," a so-called "intangible." The amount of each of these items of cost will vary with the extent of the operations of the company and somewhat with other local conditions. If they, or any items of value, are omitted or slighted in making up the total value of a plant, with a resulting total below the fair and reasonable, the rate per cent. of return upon that total earned and divided must be made correspondingly higher before new capital will be interested. Free capital will not move until satisfied that the value with which it is proposed to merge it is having full and fair consideration.

"Going value" is a particularly interesting subject for discussion, and I regret to leave it with such scant mention.

These briefly are my ideas on some of the items in the valuation of a gas property. There is much more to be said of them, and there are other items of importance in our general problem that must have your attention at some time. Among these, and of great importance, is the method of arriving at the probable cost to produce and deliver the gas. Again, I regret not to be able to discuss them all to a conclusion.

So far this discussion of the duties of public utility commissions has comprehended only the conditions of normal times. It is important to consider the duty of state gas commissions to the public and to the gas industry as affected by the unprecedented conditions created by the great war. I believe we will agree that the war has provoked an immediate need for help to tide our industry over the financial rocks and shoals that threaten to cripple it in its hour of greatest usefulness to individual and to nation.

The current rates for gas were fixed under conditions of costs greatly different from the present. In most instances there now are not sufficient earnings for dividends, and in many instances the receipts are not sufficient for the payment of operating costs. Practically nowhere do the earnings support the credit necessary to enable operating companies to meet the demands for new construction or for the renewal of maturing obligations.

The slow and exact processes of commission regulation, entirely proper and to be desired by all concerned in time of peace, must be temporarily abandoned to meet the exigencies of war times. That such exigencies exist is one of the many unfortunate conditions created by the war, and it is a condition which must be recognized and rectified. It is an unusual condition and calls for unusual treatment. The logical remedy appears to be in line with precedents already established—the arbitrary fixing of rates and standards as a war measure by the war-making authority—the Federal Government. The power to declare and carry on war carries with it by implication the power to adopt the measures necessary for the successful prosecution of the war. One of the measures necessary for the successful prosecution of the war is the maintenance of necessary industries. The industry which we are discussing is essential to the development of the full power of the nation. It cannot be maintained without immediate and radical changes in standards or rates, or both. It cannot be extended to meet the increased demands of war times without assistance.

If the above be sound, this is a matter with which the Federal Government must concern itself. The present duty of state commissions appears to be to sympathetically aid the gas companies so far as may be in their efforts to serve the people as well as conditions permit, in these months of difficulty, and to encourage and second the Federal Government in any action it may take toward maintaining or re-establishing the financial credit of the industry. But, since public utility commissions are directly charged with the responsibility to the people to maintain and develop the industry, protecting the citizen in his right to a gas supply and the supplier in his right to a profit, they are not doing their full duty, unless in the absence of Federal action, or pending Federal action, they take full care of these their charges.

It is probable that at this time no opportunity for investment that does not involve the patriotic motive, or offer a prospect of returns far greater than may he hoped from any public utility stock, will attract capital. It is improbable that free capital can be induced to investment in extensions to gas plants to meet conditions of demand that may cease with the war. Yet, for the certain success of the war, such extensions must be made. Also, if gas companies could, unassisted, raise the funds necessary, it is not just to require of them that they make extensions of plant that will cease to be profitable as soon as the war ends—and may so remain indefinitely. The discussion of this point is academic —for gas companies cannot raise money for such purposes. It is out of their power. The Government, Federal or State, must advance the money. It should be arranged on terms that insure that the gas company concerned ultimately shall repay the full value to it of the governmentally financed extensions.

The British gas companies, naturally having suffered greatly from the war-created conditions in the labor and materials markets, have sought relief in Parliament, and a Parliamentary committee has reported on the matter. The first paragraph of its report reads:

"That, with the view of maintaining in the public interest the stability of gas undertakings, some provisions should be made for the temporary modification of statutory requirements with regard to price and dividends in the case of gas undertakings whose financial circumstances have been injuriously affected by causes arising out of the war."

The military importance of maintaining the credit of public service industries in this time of war is recognized by Hon. John Skelton Williams, Comptroller of the Currency, who in his annual report to the Congress says:

"The corporations referred to supply light, heat, power and electric railway transportation for passengers and freight. They touch intimately the daily life of the people. . . . . Now they are threatened with ruin. If they are allowed to sink into inefficiency, much of the most important war work of the Government will be crippled or paralyzed.

". . . . It is essential that forbearance and consideration be exercised by the State commissions and municipal authorities, and that the corporations also be permitted to make such additions to their charges for service as will keep in them the breath of solvency, protect their owners against unjust loss, and give them a basis of credit on which they may obtain the funds with which to meet the strain put on them by the Government's needs. The breaking down of these corporations would be a national calamity.

"Because of the gravity of the situation in this regard, I am moved to ask for it the careful attention of the Congress and the public. I am impressed with the importance of early consideration by the Congress of some measure to provide directly or indirectly for advance of funds on some conservative basis to such of these corporations as need help most urgently, so that they can give adequate service to the Government. The remedy would be unusual; but the times are unusual."

By Secretary McAdoo in a letter to the President:

"Our public service utilities are closely connected with and are an essential part of our preparations for and successful prosecution of the war, and the unfavorable tendencies which the accompanying papers reveal may most effectively be checked, wherever they may be found to exist, and the needed relief obtained, only by prompt action on the part of the respective local authorities.

"I earnestly hope that you may feel justified in expressing the conviction that the vital part which the public utilities companies represent in the life and war-making energy of the nation ought to receive fair and just recognition by State and local authorities."

By President Wilson in a letter to Secretary McAdoo:

"I fully share the views you express regarding the importance of the public utilities as a part of our national equipment, especially in war time. It is essential that these utilities should be maintained at their maximum efficiency and that everything reasonably possible should be done with that end in view."

Since the above declarations of authority were written, it has been announced from Washington that the Federal Government will not undertake the fixing of prices of public utility companies. On this subject, and referring particularly to trolley and lighting companies, Mr. Tumulty has recently written the Mayor of New Orleans in part as follows:

"The conditions under which such companies operate in different parts of the country vary by so wide a variation that no common rule, it would appear, or method of relief could be applied to them. And it is the President's judgment that it is imperatively necessary that local and State authorities should take the action necessary for immediate relief."

Therefore, the obligation of protecting the public service industries on this vital point and in this critical hour remains with the State commissions. Mr. Wilson and his aids have amply set out the necessity for action.

The public utility operators confidently expected that the recently formed War Finance Corporation would greatly aid them in overcoming their war-created difficulties of raising money for demanded extensions, but the construction of the language of the bill by the directors of the Corporation and by the Attorney General of the United States has disappointed this expectation. The War Finance Corporation is not able to lighten this portion of the load of responsibility now resting on public utility commissions.

The opportunity for helpful work toward Mr. Fisher's ideal in the office of public utilities commissioner can hardly be overstated, whether in time of war or in time of peace.

The old distrust and antagonism between gas companies and their customers, distressing to both, were born of misunderstandings. Some measure of misunderstanding is inevitable between the purveyor and purchaser of a commodity that is used as wanted—without coincident knowledge of the amount being used—and paid for as the use is indicated on a device of the purveyor, little understood and altogether unchecked by or for the customer. Such distrust and antagonism have greatly diminished in recent years and must entirely disappear and mutual confidence and co-operation be established, if under wisely administered commission rule with its assurance of justice to seller and purchaser, and its element of hope for all.

The dignity of the office of Commissioner in control of an industry must be in proportion to the importance of the industry's part in the life of the people. A call to take on the duties of a Public Utility Commissioner is a call to an obligation to protect, develop and regulate an industry vast and important to the citizen and to the State; it is a call to a position of great dignity and of the highest potential usefulness.

In the office of Commissioner, bearing the delegated authority of the State—clothed with well-nigh sovereign powers over one of the greatest and most useful industries of modern days, with a large measure of the comfort and safety of millions of people, and the security of hundreds of millions of invested savings depending upon his judgment and good intent, in such a position any man—however great his attainments, however exalted his character, may find full opportunity for the exercise of his highest faculties and the satisfaction of his highest ambitions. It is a position of heavy responsibility to be desired only by men of clear and open minds, who feel in themselves the power of self sacrifice for a cause. Not even on the bench does character more become a man; and whatever we may say of aims to be attained, standards to be adopted, systems to be followed, now that gas companies are under commission rule, we must depend upon the character of the commissioners for escape from the usual deadening effect of the governmental hand on industry and for the success of the effort to make and maintain the public service corporations what Mr. Fisher nominates "effective instruments for the service of the individual citizen and the development of the organized community." There is no place on a public utility commission for a faddist or a demagogue.

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS. II. THE ELECTRICAL CONDUCTANCE OF TRIMETHYL-PARA-TOLYL-AMMONIUM IODIDE IN WATER AND SEVERAL ORGANIC SOLVENTS.*

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ALTHOUGH the theory of electrolytic dissociation has been fully substantiated for dilute aqueous solutions, investigation in the field of non-aqueous solutions has not been attended with such satisfactory results, and laws which have been found to hold for the former have been found to apply only approximately, and in some cases not at all, to the latter. With the progress of investigation, it has become more and more evident that a great deal of systematic research must still be carried out in the field of non-aqueous solutions before a comprehensive and valid theory of solutions can be formulated. As a result of numerous investigations during the past fifteen years, it is now evident that the capacity for dissociation of those substances which are recognized in water as electrolytes occurs more or less distinctly in other solvents; and, further, that the dissociating power of the solvent is related to other of its physical properties. This has been discussed in a previous paper.[1]

The most comprehensive investigation of the applicability of the theory of electrolytic dissociation to non-aqueous solutions has been carried out by Walden,[2] who has made a systematic study of the electrolytic conductivity of solutions in almost every type of organic liquid, including representatives of the alcohols, aldehydes, ketones, acids, acid anhydrides, chlorides, bromides, amides, esters, nitriles, thio-cyanates, and nitro-compounds. To facilitate the comparison of the dissociating power of the different solvents and to determine the influence of the constitution of the solvents on electrolytic dissociation, one solute —tetraethyl-ammonium iodide—was employed throughout. The results of this investigation show that the most important relation between the dissociating power of a solvent and its other physical properties, so far discovered, is that which exists between the dissociating power and the dielectric constant of the solvent.

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* Communicated by Professor Creighton.

[1] Creighton, H. J .M., JOUR. FRANKLIN INST., **182**, 745 (1916).

[2] Walden, P., *Zeitschr. phys. Chem.*, **54**, 129 (1905).

Recently, Davis[3] has studied the electrical conductivity of solutions of fuchsine—a solute containing the benzol nucleus—in a few non-aqueous solvents. His results show that the behavior of solutions of this solute is practically the same as that of solutions of tetraethyl-ammonium iodide in the same solvents.

The present investigation was undertaken to study more fully the electrolytic conductivity of solutions of a different type of solute containing the benzol nucleus, *viz.*, trimethyl-para-tolyl-ammonium iodide.

The solvents employed embrace various types of organic substances exhibiting different constitutive factors, and belong to the following classes of compounds:

1. Water.
2. Alcohols: methyl alcohol, ethyl alcohol.
3. Aldehydes: propyl aldehyde, benzaldehyde, anisaldehyde.
4. Ketones: acetone.
5. Acids: formic acid, acetic acid.
6. Nitriles: propionitrile, benzonitrile.
7. Nitro-compounds: nitromethane, nitrobenzol.
8. Epichlorhydrin.

A number of other solvents were used, but in these the solute was so slightly soluble that the results of the conductivity measurements were of little or no value.

The trimethyl-para-tolyl-ammonium iodide — $C_7H_7N(CH_3)_3I$ —used in the following experiments was readily soluble in water, from which it crystallized in pale yellow plates or needles;

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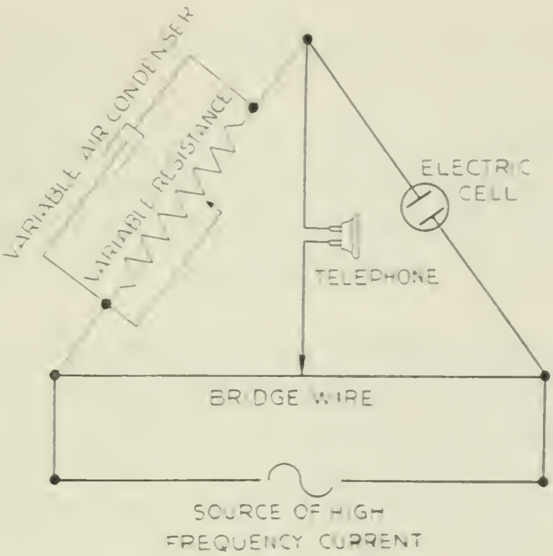
[3] Davis, H. S., *Proc. and Trans.* Nova Scotian Inst. Sci., 13, 40 (1912).

from dilute solutions in the former form, and from concentrated solutions in the latter. By filtering a solution of the salt through animal charcoal the yellow color was removed, and on allowing the filtrate to crystallize slowly very beautiful colorless crystalline plates were obtained. The salt was purified by repeated recrystallization from water, the influence of recrystallization on the purity of the salt being followed by measuring the specific conductivity of its aqueous solutions.

The Kohlrausch-Ostwald method with the Wheatstone bridge arrangement and the telephone was employed for measuring the electrolytic conductivity of the solutions. The bridge wire was mounted on a marble cylinder and was about 500 cm. in length. The high frequency current was produced by a motor-driven toothed wheel revolving between the pole faces of a magnet. The capacity of the electrolytic cell was balanced by means of a variable air condenser. The conductivity cell was of the Ostwald type, and the size of the electrodes was varied with the nature of the solution used. The platinum electrodes were platinized. The arrangement of the apparatus is shown diagrammatically in Fig. 1. The thermostat was heated electrically, and by means of an electric regulator the temperature could be kept constant within 0.01°.

FIG. 1.



Below are given the symbols employed in this paper:

v = the number of liters which contain one mole of the solute;
t = the temperature of the experiment in degrees Centigrade;
κ_0, κ_{18} and κ_{25} = the specific conductivity of the solvent at $t = 0°$, $t = 18°$, and $t = 25°$;
κ' = the specific conductivity of the solution;
$\Lambda = (\kappa'_t - \kappa_t)\, v\, .10^3$ = the equivalent conductivity of the solution after being corrected for the conductivity of the pure solvent;
$\Lambda \infty$ = the equivalent conductivity at infinite dilution;
$\alpha = \dfrac{\Lambda v}{\Lambda \infty}$ = the degree of dissociation of the electrolyte;
$k = \dfrac{\alpha^2}{(1-\alpha)_v}$ = the dissociation constant (Ostwald);
ε = the dielectric constant of the solvent at 20°;
$c = \dfrac{\Lambda_v^{t_2} - \Lambda_v^{t_1}}{(t_2 - t_1)\Lambda_v^{t_1}}$ = the temperature coefficient of equivalent conductivity.

All conductivity values are expressed in reciprocal ohms.

A 0.02 *n.* aqueous solution of potassium chloride was used to determine the cell constants of the conductivity vessels, the specific conductivity of this solution at 25° being taken as 0.002768.[4]

Since the pure solvents employed in the following experiments often possessed an appreciable conductivity, it was necessary to take this into consideration when calculating the conductivity of the dissolved solute. As the observed conductivity of the solution is made up of the sum of the conductivities of the solute and the solvent, the conductivity of the former may be ascertained by subtracting from the measured specific conductivity of the solution the specific conductivity of the solvent.

In most cases in the tables which follow, the limiting value of the equivalent conductivity, $\Lambda \infty$, has been calculated by means of the formula[5]:

$$\Lambda \infty = \frac{\sqrt[3]{v_2} \cdot \Lambda_2 - \sqrt[3]{v_1} \cdot \Lambda_1}{\sqrt[3]{v_2} - \sqrt[3]{v_1}}$$

In a few cases it has been ascertained by extrapolation of the curve showing the change in the equivalent conductivity with dilution.[6]

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[4] Findlay, A., "Practical Physical Chemistry," p. 181 (1914).

[5] Kohlrausch-Holborn, "Leitvermögen der Elektrolyte," p. 107 (1898).

[6] Ostwald-Luther, "Physiko-Chemische Messungen," p. 481 (1910).

I. WATER:

The water used for the preparation of the aqueous solutions of trimethyl-para-tolyl-ammonium iodide was purified by the method of Jones and Mackay,[7] and had a specific conductivity of 1.8×10^{-6}. It was kept in bottles which had been employed for years for this purpose, and measurements from time to time showed that even after standing for several weeks in these bottles the conductance of the water did not change appreciably.

Trimethyl-para-tolyl-ammonium iodide was found to be readily soluble in water, producing a solution with a pale yellow color. The conductivity of these solutions was measured at 25°, and 0°. The results obtained are recorded in Table I.

TABLE I.

$\kappa_{25} = 1.867 \times 10^{-6}$.

$t = 25°$ $v =$	29.31	58.62	117.24	234.48	468.96	937.92	1875.84	∞
$\kappa' \times 10^3 =$	3.202	1.686	0.8761	0.4513	0.2308	0.1182	0.06085	
$\Lambda =$	93.79	98.72	102.5	105.4	107.4	109.2	110.7	
$\Lambda_\infty =$		....	117.4	116.6	115.1	116.0	116.2	116
$\alpha =$	0.809	0.851	0.884	0.909	0.926	0.941	0.955	1.00
$t = 0°$			$\kappa_0 = 2.0 \times 10^{-6}$.					
$\kappa' \times 10^3 =$	1.698	0.9031	0.4667	0.2390	0.1229	0.06350		
$\Lambda =$	49.71	52.87	54.49	55.57	56.68	57.69		
$\Lambda_\infty =$		....	60.8	61.4	60.9	61.6		61
$\alpha =$	0.815	0.867	0.893	0.911	0.929	0.946		1.00
$c_{0-25} =$	0.0355	0.0347	0.0352	0.0359	0.0358	0.0357	...	0.0361
		Mean temp. coeff. = 0.0355						

In Fig. 2 the cube roots of the concentrations (*i.e.*, $\frac{1}{\sqrt[3]{v}}$, which represents the reciprocal mean common interval of the electrolytic molecules) are plotted as abscissæ against the corresponding equivalent conductivities as ordinates.

As is to be expected, the data contained in Table I show that trimethyl-para-tolyl-ammonium iodide, like other tetra-substituted ammonium salts, is largely dissociated at moderate dilutions. Like the majority of strong electrolytes, the dissociation constant of trimethyl-para-tolyl-ammonium iodide, as calculated from Ostwald's dilution law, varies with the concentration of the solution (see Table II).

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[7] Jones, H. C., and Mackay, E., *Amer Chem. J.*, 19, 283 (1897).

The theoretical grounds for the apparent break-down of the dilution law in the case of strong electrolytes have been the source of much investigation, and as a result it is now generally conceded that the law of mass action will have to be modified or supplemented. Values for the degrees of dissociation of strong electrolytes, derived from conductivity measurements, may be incorrect, owing to the fact that the mobility of the ions cannot be assumed constant, on account of the change of ionic friction with variation in concentration. Jahn[8] has shown that the degrees of dissociation of strong electrolytes derived from conductivity data are too high. On the other hand, the deviation of strong electrolytes from the dilution law may be ascribed to certain chemical causes, such as the formation of inner complexes (the addition of undissociated molecules of the electrolyte to its ions), which, as the results of the investigations of Bredig,[9] Noyes,[10] Steele,[11] and Donnan, Bassett and Fox,[12] show, probably occurs even in solutions of salts of the alkali metals, while in solutions of salts of less electro-positive metals the formation of these complexes has been established beyond doubt. Biltz[13] has arranged the univalent ions according to their tendency to form inner complexes in the following order, this tendency increasing from left to right:

$$Cs^+,\ Rb^+,\ K^+,\ NH_4^+,\ Na^+,\ Li^+,$$
$$NO_3^-,\ Cl^-,\ Br^-,\ F^-,\ I^-.$$

In view of the position of the ammonium and iodine ions, it might well be expected that trimethyl-para-tolyl-ammonium iodide would give results which are not in accordance with the dilution law. Another cause to which failure of the dilution law may be due, is the union of the ions of the electrolyte with the solvent, which phenomenon has been very fully studied by Jones and his co-workers.[14]

Several empirical formulæ have been proposed to express the relation between the degree of dissociation $\left(\alpha = \frac{\Lambda_v}{\Lambda_\infty}\right)$ and the concentration for strong electrolytes. That of Rudolphi,[15] which differs from the dilution law in that the square root of the dilution is substituted for the dilution, has the form:

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[8] Jahn, H., *Zeitschr. phys. Chem.*, 33, 545 (1900).

[9] Bredig, G., *Zeitschr, phys. Chem.*, 13, 262 (1894).

[10] Noyes, A. A., *Ibid.*, 36, 63 (1901).

[11] Steele, B. D., *Ibid.*, 40, 722 (1902).

[12] Donnan, F. G., Bassett, H., and Fox, J. J., *J. Chem. Soc.*, 81, 944 (1902).

[13] Biltz, W., *Zeitschr. phys. Chem.*, 40, 185 (1902).

[14] Jones, H. C., JOUR. FRANKLIN INST., 176, 479, 677 (1913).

$$\frac{\alpha^2}{(1-\alpha)\sqrt{v}} = k_1$$

According to van't Hoff,[16] the ratio of the cube of the ionic concentration to the square of the concentration of the undissociated molecules is constant, *i.e.*,

$$\frac{\alpha^3}{(1-\alpha)^2 v} = \text{constant}$$

or simplified,

$$\frac{\alpha^{\frac{3}{2}}}{(1-\alpha)\sqrt{v}} = k_2.$$

It has been suggested by Storch[17] that a general expression in the form

$$(\alpha c)^n = k_3(1-\alpha)c,$$

or

$$\frac{\alpha^n}{(1-\alpha)\,v^{n-1}} = k_3$$

be employed, the exponent n being varied as required with different electrolytes. The values calculated for trimethyl-para-tolyl-ammonium iodide with these formulæ, as well as those obtained with the dilution law, are given in Table II, and although the values are more constant (especially in the case of the Storch formula) than those given with the dilution law, nevertheless their theoretical basis is unexplained.

TABLE II.

Values for k for trimethyl-para-tolyl-ammonium iodide at 25°.

v	α	$k = \frac{\alpha^2}{(1-\alpha)v}$.	$k_1 = \frac{\alpha^2}{(1-\alpha)\sqrt{v}}$.	$k_2 = \frac{\alpha^{\frac{3}{2}}}{(1-\alpha)\sqrt{v}}$.	$k_3 = \frac{\alpha^n}{(1-\alpha)v^{n-1}}$. $n = 1.40$.
24.31	0.809	0.117	0.633	0.495	1.01
58.62	0.851	0.083	0.635	0.473	1.07
117.24	0.884	0.058	0.622	0.433	1.08
234.48	0.909	0.039	0.593	0.387	1.08
468.96	0.926	0.025	0.535	0.309	1.04
937.92	0.941	0.016	0.490	0.255	1.01
1875.84	0.955	0.011	0.468	0.229	1.02
				Mean:	1.04

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[15] Rudolphi, M., *Zeitschr. phys. Chem.*, **17**, 385 (1895).

[16] van't Hoff, J. H., *Ibid.*, **18**, 300 (1895).

[17] Storch, L., *Ibid.*, **19**, 13 (1896).

Since, according to Kohlrausch's law of the independent migration of ions, the equivalent conductance of an electrolyte at infinite dilution is equal to the sum of the individual conductances of its ions, *i.e.*,

$$\Lambda_\infty = l_c + l_a.$$

it follows that at 25° the conductance of the trimethyl-para-tolyl-ammonium ion is

$$\begin{array}{lr} \Lambda_\infty = l_{C_7H_7N(CH_3)_3^+} + l_{I^-} & = 116 \\ l_{I^-} & = 75.7^{18} \\ \hline l_{C_7H_7N(CH_3)_3^+} & = 40.3 \end{array}$$

II. ALCOHOLS.

As representatives of this class of solvent, methyl and ethyl alcohols were employed.

The small electrolytic conductivity of these alcohols indicates the presence of ions which are probably formed in the manner illustrated by the following equations:

$$R.OH \rightleftharpoons (RO)^- + H^+;$$
$$R.OH \rightleftharpoons R^+ + (OH)^-;$$
$$R.OH \rightleftharpoons R^+ + H^+ + O^{--}.$$

Methyl Alcohol.

The methyl alcohol ("Kahlbaum") was dried for a long time over lime and then purified by fractional distillation, the portion boiling at 65.8° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were slightly yellow in color. The results of the conductivity measurements of solutions of the electrolyte in this solvent are given in Table III.

TABLE III.

$\kappa_{25} = 1.31 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.060	1.142	0.6164	0.3228	0.1700	0.0888	0.0460	
$\Lambda =$	65.9	73.0	78.5	82.3	86.4	89.6	91.5	
$\Lambda_\infty =$	100.1	99.6	97.0	102.1	101.8	99.0		100
$\alpha =$	0.66	0.73	0.79	0.82	0.86	0.90	0.92	1.00

The variation of the equivalent conductivity of trimethyl-para-tolyl-ammonium iodide in methyl alcohol with concentration is expressed graphically in Fig. 2.

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[18] Washburn, E. W., "Principles of Physical Chemistry," p. 214 (1915).

Ethyl Alcohol.

The ethyl alcohol was dried over anhydrous copper sulphate and purified by fractional distillation, the portion boiling at 78.4° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were slightly yellow in color. The results of conductivity measurements of the electrolyte in this solvent at 25° and 0° are given in Table IV.

TABLE IV.

$\kappa_{25}=4.331\times10^{-7}$.

$t=25°$ $v=$	16	32	64	128	256	512	1024	2048	∞
$\kappa'\times10^3=$	1.283	0.7514	0.4333	0.2480	0.1396	0.0758	0.0396	0.0208	
$\Lambda\ =$	20.53	24.03	27.70	31.69	35.63	38.61	40.15	41.78	
$\Lambda_\infty=$	....	(41.9)	46.9	50.8	50.1	46.0	48.1		48
$\alpha=$	0.43	0.50	0.58	0.66	0.74	0.80	0.84	0.87	1.00
$t=0°$				$\kappa_0=3.777\times10^{-7}$.					
$\kappa'\times10^3=$	0.7410	0.4393	0.2580	0.1475	0.0819	0.0451	0.0239	....	
$\Lambda\ =$	11.85	14.05	16.49	18.83	20.86	22.89	24.07	....	
$\Lambda_\infty=$	....	25.8	27.9	28.7	30.7	28.6	....		28
$\alpha=$	0.42	0.50	0.59	0.67	0.75	0.82	0.86	....	1.00
$c_{0-25}=$	0.0293	0.0284	0.0272	0.0273	0.0283	0.0275	0.0267	....	0.0285
			Mean temp. coeff. $=0.0278$						

The variation of the equivalent conductivity of the electrolyte in ethyl alcohol with change in concentration is expressed graphically in Fig. 2.

Of the different physical properties of a solvent which influence its dissociating power, by far the most important is the dielectric constant. According to the Nernst[19]-Thomson[20] hypothesis, there exists between these two properties a close parallelism. The researches of Dutoit and Aston [21] have led these investigators to conclude that only those solvents which are highly associated possess dissociating power, while Dutoit and Friderich[22] have come to the conclusion that the electrolytic conductivity of a solute in a non-associated solvent is zero. Regarding the influence of the association of a solvent on its dissociating power, it should be pointed out that solvents which are largely associated invariably have high dielectric constants. The reverse is not true, however, for many solvents with high dielectric constants are not associated.

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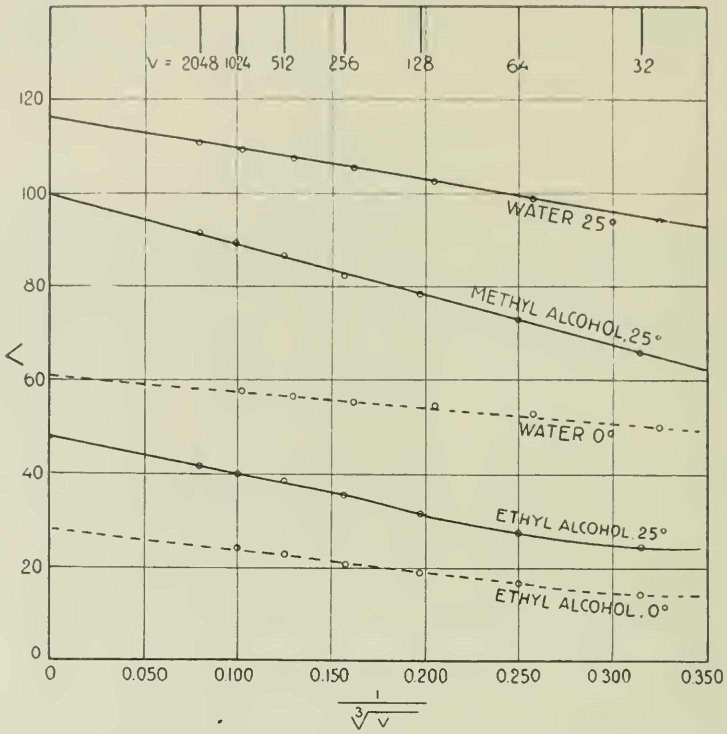
[19] Nernst, W., *Zeitschr. phys. Chem.*, **13**, 535 (1894).

[20] Thomson, J. J., *Phil. Mag.* (v), **36**, 313 (1893).

[21] Dutoit, P., and E. Aston, *Compt. rend.*, **125**, 240 (1897).

[22] Dutoit, P., and L. Friderich, *Bull. Soc. Chim.* (3), **19**, 321 (1898).

FIG. 2.



How far the results obtained at 25° for solutions of trimethyl-para-tolyl-ammonium iodide in water (which may be regarded as the first representative of the homologous alcohol series), methyl alcohol and ethyl alcohol are in agreement with these conclusions will be seen from the data given in Table V.

TABLE V.

Solvent.	Degree of Association.[23]	Dielectric constant. ϵ	Λ_∞	Dissociation of $C_7H_7N(CH_3)_3I$ at v = 32	1024	2048
				per cent.	*per cent.*	*per cent.*
Water, HOH	3.81	81.7[24]	116	82	94	96
Methyl alcohol, CH_3OH	3.43	32.5[24]	100	66	90	92
Ethyl alcohol, C_2H_5OH	2.74	25.4[25]	48	50	84	87

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[23] Ramsay, W., and J. Shields, *Zeitschr. phys. Chem.*, **12**, 468 (1898).

[24] Drude, P., *Ibid.*, 23, 308 (1897).

[25] Walden, P., *Ibid.*, **70**, 573 (1910).

It will be observed that these three solvents are able to dissociate trimethyl-para-tolyl-ammonium iodide to a considerable extent, and that the nearer the alcohol stands to water as the first representative of the series, the smaller are the increases in the degree of dissociation between $v = 32 - 1024$:

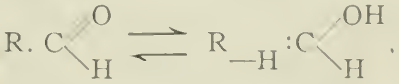
for water, $\alpha_{1024} - \alpha_{32} = 12$
for methyl alcohol, $= 26$
for ethyl alcohol, $= 37$.

These differences in the increments show that the value for the degree of dissociation of the electrolyte increases more rapidly with dilution the further the alcohol stands from water. Further, it will also be seen that the value for the equivalent conductivity at infinite dilution is greater the nearer the alcohol stands to water.

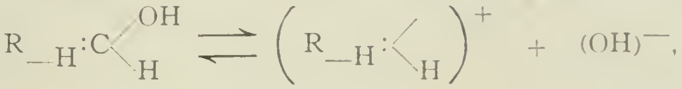
III. ALDEHYDES.

As representatives of this class of compounds propyaldehyde, benzaldehyde and anisaldehyde were employed.

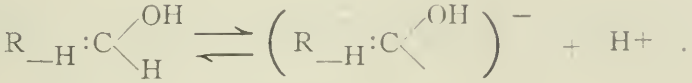
According to Walden,[26] the auto-ionization of aldehydes, the occurrence of which is indicated by their small electrolytic conductivity, may be brought about by a molecular rearrangement:



with the subsequent occurrence of amphoteric dissociation:



and



Propylaldehyde.

The aldehyde was purified by fractional distillation, the fraction boiling at 68.5° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were of a yellow-brown color. The color of these solutions decreased in intensity on standing, but their conductivity did not exhibit a corresponding change.[27] In Table VI are recorded the results of the conductivity measurements at 25°.

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[26] Walden, P., *Zeitschr. phys. Chem.*, 46, 137 (1903).

[27] Walden observed a similar phenomenon with solutions of tetra-ethyl-ammonium iodide in propylaldehyde: *Zeitschr. phys. Chem.*, 54, 147 (1905).

TABLE VI.

$\kappa_{25} = 0.98 \times 10^{-6}$.

$t = 25°$ $v =$	64	128	256	512	1024	∞
$\kappa' \times 10^3 =$	1.055	0.5904	0.3415	0.1809	0.0984	
Λ =	67.50	75.43	87.16	92.11	99.78	120[28]
α =	0.56	0.63	0.73	0.77	0.83	1.00

The change in equivalent conductivity with concentration is shown graphically in Fig. 3.

Benzaldehyde.

The benzaldehyde employed in the following measurements was purified by crystallization and distillation, and had a boiling point of 179°. Trimethyl-para-tolyl-ammonium iodide was found to be fairly soluble in this solvent. The solutions were of a reddish-brown color. The results of conductivity measurements at 18° and 25° are given in Table VII.

TABLE VII.

$\kappa_{25} = 1.93 \times 10^{-7}$.

<table>
<tr><td>$t = 25°$ $v =$</td><td colspan="2">64</td><td colspan="2">128</td><td colspan="2">256</td><td colspan="2">512</td><td colspan="2">1024</td><td>∞</td></tr>
<tr><td>$\kappa' \times 10^3 =$</td><td colspan="2">2.522</td><td colspan="2">1.512</td><td colspan="2">0.8695</td><td colspan="2">0.4762</td><td colspan="2">0.2633</td><td></td></tr>
<tr><td>Λ =</td><td colspan="2">16.14</td><td colspan="2">19.33</td><td colspan="2">22.20</td><td colspan="2">24.28</td><td colspan="2">26.20</td><td></td></tr>
<tr><td>Λ_∞ =</td><td></td><td colspan="2">31.6</td><td colspan="2">33.3</td><td colspan="2">32.2</td><td colspan="2">33.5</td><td></td><td>33</td></tr>
<tr><td>α =</td><td colspan="2">0.49</td><td colspan="2">0.59</td><td colspan="2">0.67</td><td colspan="2">0.74</td><td colspan="2">0.79</td><td>1.00</td></tr>
<tr><td>$t = 18°$.</td><td colspan="10">$\kappa_{18} = 1.70 \times 10^{-7}$.</td><td></td></tr>
<tr><td>$\kappa' \times 10^3 =$</td><td colspan="2">2.288</td><td colspan="2">1.344</td><td colspan="2">0.7841</td><td colspan="2">0.4304</td><td colspan="2">0.2327</td><td></td></tr>
<tr><td>Λ =</td><td colspan="2">14.63</td><td colspan="2">17.18</td><td colspan="2">20.03</td><td colspan="2">21.95</td><td colspan="2">23.66</td><td></td></tr>
<tr><td>Λ_∞ =</td><td></td><td colspan="2">27.0</td><td colspan="2">31.0</td><td colspan="2">29.3</td><td colspan="2">30.0</td><td></td><td>29</td></tr>
<tr><td>α =</td><td colspan="2">0.50</td><td colspan="2">0.59</td><td colspan="2">0.69</td><td colspan="2">0.76</td><td colspan="2">0.82</td><td>1.00</td></tr>
<tr><td>$c_{18-25} =$</td><td colspan="2">0.0147</td><td colspan="2">0.0180</td><td colspan="2">0.0155</td><td colspan="2">0.0152</td><td colspan="2">0.0153</td><td>0.0197</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="6">Mean temp. coeff. = 0.0157</td><td colspan="2"></td><td></td></tr>
</table>

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 3.

Anisaldehyde.

Owing to our supply of anisaldehyde being very limited, purification was not attempted; however, its specific conductivity indicated a high degree of purity. Its boiling point was 248.2°.

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[28] This value was derived by graphic extrapolation.

Trimethyl-para-tolyl-ammonium iodide was found to be readily soluble in this solvent, the solutions being almost colorless. The results of the conductivity measurements at 25° are given in Table VIII.

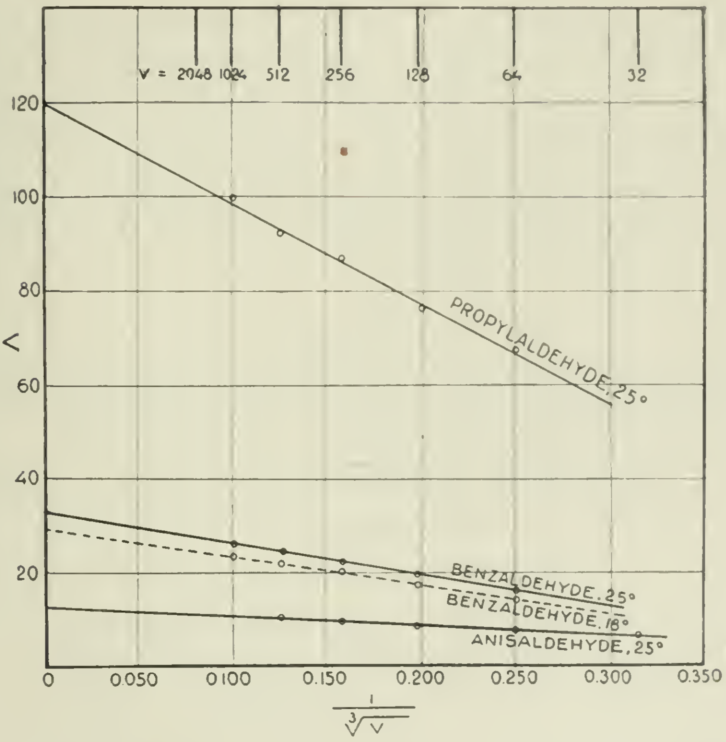
TABLE VIII.

$\kappa_{25} = 2.229 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	∞
$\kappa' \times 10^3 =$	2.006	1.211	0.7045	0.3790	0.2284	
$\Lambda =$	6.35	7.61	8.73	9.65	10.55	
$\Lambda_\infty =$		12.4	13.0	13.2	13.6	13
$\alpha =$	0.49	0.59	0.67	0.74	0.81	1.00

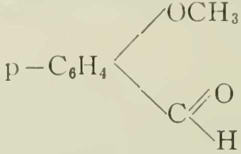
The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 3.

FIG. 3.



For the purpose of comparison, the percentage dissociation at different dilutions of trimethyl-para-tolyl-ammonium iodide in propylaldehyde, benzaldehyde and in anisaldehyde at 25°, together with the dielectric constants of these solvents, is given in Table IX. As in the case of alcohols, it will be observed that a parallelism exists between the extent of the dissociation of the solute at a given dilution and the magnitude of the dielectirc constant. The degree of association of each of these solvents is fairly small.

TABLE IX.

Solvent.	Dielectric Constant.	∞	Dissociation of $C_7H_7N(CH_3)_3I$ at v =		
			64	256	1024
			per cent.	*per cent.*	*per cent.*
Propylaldehyde, C_2H_5CHO	18.5[29]	120	56	73	83
Anisaldehyde,  $p-C_6H_4{<}^{OCH_3}_{C{<}^{O}_{H}}$	15.5[30]	13	59	74	..
Benzaldehyde, C_6H_5CHO	14.5[31]	33	49	67	79

IV. KETONES.

It was our intention to study the electrical conductivity of solutions of trimethyl-para-tolyl-ammonium iodide in an aliphatic ketone and in one containing the benzol ring. For the latter acetophenone was chosen, but, unfortunately, the solubility of the solute was extremely small in this solvent. Consequently, acetone is the only representative of this class of organic compound that we have employed.

Acetone.

Walden has suggested[32] that the auto-dissociation of acetone may result from a direct ionization of the molecule:

$$CH_3.CO.CH_3 \rightleftharpoons (CH_3.CO.CH_2)^- + H^+;$$

or, first an intramolecular rearrangement may occur:

$$CH_3.CO.CH_3 \rightleftharpoons CH_2:C(OH)CH_3,$$

and then this new product may undergo ionization:

$$CH_2:C(OH)CH_3 \rightleftharpoons CH_2:C(O—)CH_3^- + H^+.$$

Acetone prepared from the bisulphite compound was employed in the following measurements. This product was allowed to stand for several days over anhydrous copper sulphate, and was then further purified by fractional distillation, the portion boiling between 56° and 57° being used. Trimethyl-para-tolyl-ammonium iodide was difficultly soluble in this solvent, an $\frac{N}{128}$ solution being the most concentrated that could be prepared. All the solutions of the solute in this solvent were colorless. In Table X are given the results of conductivity measurements at 25° and 18°.

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[29] Drude, P., *Zeitschr. phys. Chem.*, 23, 308 (1897).

[30] Walden, P., *Ibid.*, 46, 176 (1903).

[31] Thwing, C. B., *Ibid.*, 14, 286 (1894).

[32] Walden, P., *Ibid.*, 46, 162 (1903).

TABLE X.

$\kappa_{25} = 0.370 \times 10^{-6}$.

$t = 25°$ $v =$	128	256	512	1024	∞
$\kappa' \times 10^4 =$	7.864	4.570	2.575	1.422	
$\Lambda =$	100.6	117.1	131.7	145.2	
$\Lambda_\infty =$		180.9	187.8	196.7	188
$\alpha =$	0.54	0.62	0.70	0.77	1.00
$= 18°$	$\kappa_{18} = 0.202 \times 10^{-6}$.				
$\kappa' \times 10^4 =$	6.466	3.747	2.073	1.117	
$\Lambda =$	82.74	95.87	106.0	114.1	
$\Lambda_\infty =$		146.5	144.9	145.0	145
$\alpha =$	0.57	0.66	0.73	0.79	1.00
$c_{18-25} =$	0.0308	0.0303	0.0346	0.0389	0.042
	Mean temp. coeff. = 0.0336				

The change in equivalent conductivity with variation in concentration, for the two temperatures, is shown graphically in Fig. 4. It will be observed that the curves are not parallel, but slope away from one another as the concentration decreases. This is to be expected from the increase in the value of the temperature coefficient with decrease in concentration.

The dissociating power of acetone, as expressed by the values for the degree of dissociation at the different concentrations, is about what would be expected from the value of its dielectric constant, $\varepsilon = 21.9$[33]. According to Ramsay and Shields[34] its degree of association is 1.26. It is worthy of note that the equivalent conductivity of trimethyl-para-tolyl-ammonium iodide at infinite dilution (and, therefore, the electrolytic mobilities of the ions) in acetone, which is the simplest carbon chain ketone, is very high.

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[33] Drude,, P., *Zeitschr. phys. Chem.*, **23**, 308 (1897).

[34] Ramsay, W., and J. Shields, *Ibid.*, **12**, 468 (1893).

V. ACIDS.

As representatives of this class of solvent, formic acid and acetic acid were employed. The association factors of these acids are high, being 3.61 and 3.62, respectively.[35]

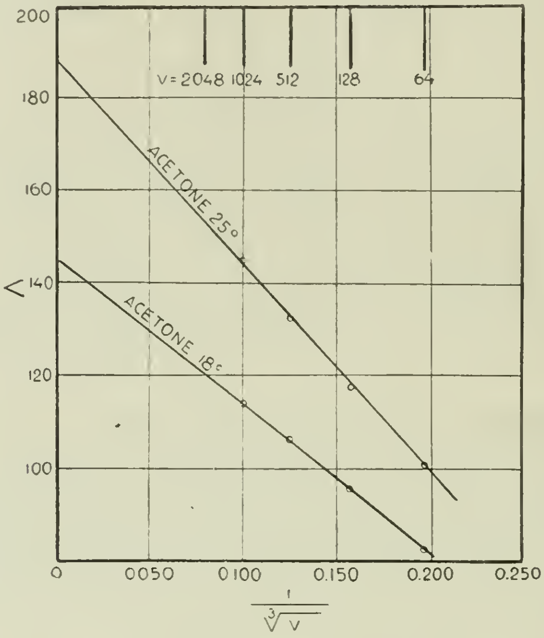
The auto-dissociation of this type of acids is represented by the following equation:

$$R.COOH. \rightleftharpoons RCOO^- + H^+.$$

Formic Acid.

The anhydrous formic acid employed in the following measurements was prepared by the method recommended by Garner, Saxton and Parker.[36] Kahlbaum's formic acid was dried for several days over anhydrous copper sulphate, and then distilled over the same dehydrating agent under a pressure of 120 millimeters of mercury. The distillate was allowed to stand over anhydrous copper sulphate again for twenty-four hours, and distilled a second time at the same pressure. The first third of the distillate was discarded. The portion used in the subsequent measurements boiled at 49.9° under a pressure of 120 millimeters

FIG. 4.



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[35] Ramsay, W., and J. Shields, *loc. cit.*

[36] Garner, J. B., B. Saxton and H. O. Parker, *Amer. Chem. J.*, **46**, 236 (1911).

of mercury. The density of this sample of formic acid was measured at 25°, and a value $d = 1.2136$ obtained.

Trimethyl-para-tolyl-ammonium iodide was readily soluble in this solvent. The freshly prepared solutions were practically colorless, but on standing gradually turned to a deep reddish-brown color.

An $\frac{N}{16}$ solution of the solute was prepared, and its conductivity measured at 25°. Solutions of greater dilutions were obtained in the usual way, by removing one-half of the solution and adding to the remainder an equal volume of pure solvent. It was found that the equivalent conductivity of these solutions increased very rapidly with dilution: $v = 16$, $\Lambda = 41.01$; $v = 256$, $\Lambda = 123.2$; $v = 1024$, $\Lambda = 363.4$. As it was evident from these very high values for Λ at the higher dilutions, that either the solute reacted with the solvent, or that the latter absorbed moisture from the atmosphere, thus greatly vitiating the observed conductivity values, solutions of each desired concentration were prepared by dissolving the requisite amount of solute and the conductivity quickly measured. The values obtained in this way for the equivalent conductivity, together with other data, are given in Table XI, where it will be observed that the Λ values show no such abnormal behavior as those given above. These values when plotted against $\frac{1}{\sqrt[3]{v}}$ lie on a straight line (Fig. 5) which when produced gives for Λ_∞ a value of 90.

TABLE XI.

$\kappa_{25} = 3.01 \times 10^{-4}$.

$t = 25°$ $v =$	16	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.558	1.605	0.937	0.511	0.280	0.146	0.0765	0.0393	
$\Lambda =$	40.93	51.36	59.97	65.41	71.68	74.75	78.33	80.49	
$\Lambda_\infty =$	91.4	93.1	90.0	92.9	86.5	91.9	89.1		90
$\alpha =$	0.45	0.57	0.67	0.73	0.80	0.83	0.87	0.89	1.00

Acetic Acid.

Glacial acetic acid was purified by repeated fractional crystallization, until a product melting at 15.9-16.0° was obtained. The melting point of pure anhydrous acetic acid is 16.7°. Since the presence of one per cent. of water lowers the melting point 2.16°, a sufficient quantity of acetic anhydride was added to our acid to combine with the 0.324 per cent. of water contained therein. The acid thus obtained had a specific conductivity of 1.69×10^{-7}, a value which agrees closely with that obtained by Walden.[37]

Trimethyl-para-tolyl-ammonium iodide was found to be but slightly soluble in acetic acid, the most concentrated solution that could be prepared being $\frac{1}{256}$ normal. Acetic acid solutions of the solute were almost colorless when first prepared, but on standing gradually turned a reddish-brown. In Table XII are given the results of conductivity measurements at 25°.

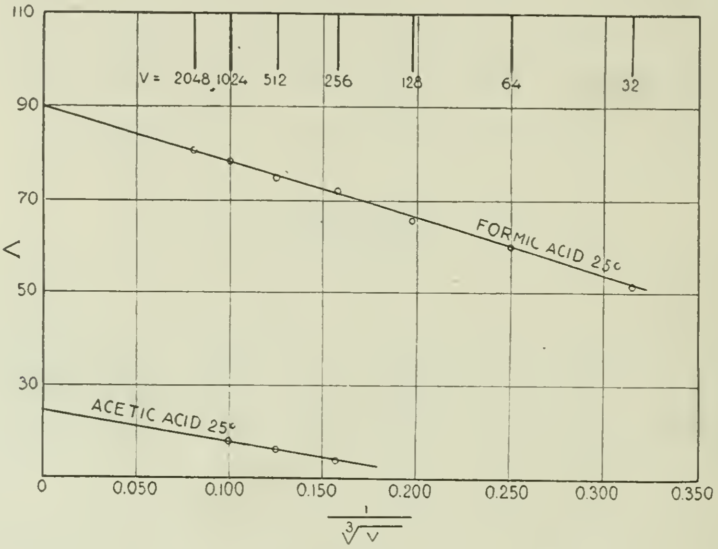
TABLE XII.

$\kappa_{25} = 1.69 \times 10^{-7}$.

$t = 25°$ $v =$	256	512	1024	∞
$\kappa' \times 10^6 =$	5.494	3.189	1.760	
$\Lambda =$	14.06	16.33	18.02	
$\Lambda_\infty =$	25.1	24.5		25
$\alpha =$	0.56	0.65	0.72	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 5.

FIG. 5.



VI. NITRILES.

As representatives of this class of solvent, an aliphatic compound, propionitrile, and an aromatic compound, benzonitrile, were employed.

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[37] Walden, P., *Zeitschr. phys. Chem.*, **54**, 159 (1905).

According to Walden,[38] the auto-ionization of nitriles may occur in two ways:

$$R.CN \rightleftharpoons R^+ + CN^-;$$

or a molecular rearrangement may first take place:

$$R.CN \rightleftharpoons (R - H):CNH,$$

followed by the ionization:

$$(R - H) : CNH \rightleftharpoons (R - H) :CN^- + H^+.$$

Propionitrile.

The propionitrile ("Kahlbaum's") was dehydrated by allowing it to stand for several weeks over anhydrous sodium sulphate, and then purified by fractional distillation. The portion boiling between 97.6 and 98.0° was employed for the following measurements. The results of the conductivity measurements are given in Table XIII.

TABLE XIII.

$\kappa_{25} = 0.281 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	1024	∞
$\kappa' \times 10^3 =$	2.165	1.311	0.753	0.414	0.222	0.117	
$\Lambda =$	69.28	83.91	96.38	106.0	113.7	119.8	
$\Lambda_\infty =$	140.2	144.2	143.1	143.3	142.3		143
$\alpha =$	0.48	0.59	0.67	0.74	0.80	0.84	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 6.

Benzonitrile.

"Kahlbaum's" preparation was dried over fused calcium chloride and then purified by fractional distillation under reduced pressure. The solubility of trimethyl-para-tolyl-ammonium iodide in this solvent was very small, and the solutions were of a pale yellow color. The results of conductivity measurements of the solute in this solvent at 25° are given in Table XIV.

TABLE XIV.

$\kappa_{25} = 0.229 \times 10^{-5}$.

$t = 25°$ $v =$	128	256	512	1024	∞
$\kappa' \times 10^4 =$	2.279	1.353	0.7605	0.4307	
$\Lambda =$	28.88	34.04	37.77	41.76	
$\Lambda_\infty =$	54.0	52.2	57.0		54
$\alpha =$	0.54	0.63	0.70	0.77	1.00

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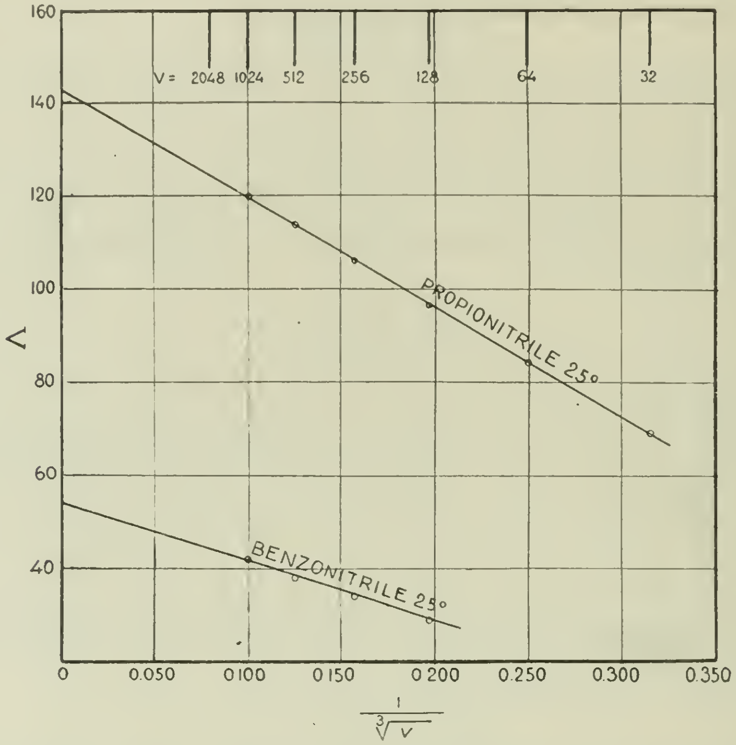
[38] Walden, P., *Zeitschr. phys;. Chem.*, 46, 155 (1903).

The change in the equivalent conductivity with variation in concentration is shown graphically in Fig. 6.

VII. NITRO-COMPOUNDS.

As representatives of this class of solvent, an aliphatic compound, nitromethane, and an aromatic compound, nitrobenzol, were selected.

FIG. 6.



Regarding the auto-ionization of this type of solvent, Walden[39] has suggested two possibilities: (1) a molecular rearrangement:

$$R.NO_2 \rightleftharpoons (R-H) : NOOH,$$

which is followed by ionization:

$$(R-H) : NOOH \rightleftharpoons (R-H) : NOO^- + H^+;$$

and (2)

$$R.NO_2 \rightleftharpoons R^+ + NO_2^-.$$

Nitromethane.

This solvent[40] was dried for several months over fused calcium chloride and then purified by fractional distillation, the portion boiling at 101° being employed. Trimethyl-para-tolyl-ammonium iodide was readily soluble in nitromethane, the solutions having a pale yellow color. The results of conductivity measurements at 25° are given in Table XV.

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[39] Walden, P., *Zeitschr. phys. Chem.*, 46, 161 (1903).

[40] We wish to express our indebtedness to Mr. J. R. Hull, of the Department of Chemistry, of Swarthmore College, for the preparation of the nitromethane we used in this work.

TABLE XV.

$\kappa_{25} = 1.32 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.275	1.275	0.698	0.369	0.193	0.1007	0.0524	
$\Lambda =$	72.77	81.54	89.22	94.21	98.30	101.8	104.7	
$\Lambda_\infty =$	115.2	118.7	113.4	114.1	115.0	115.8		115
$\alpha =$	0.63	0.71	0.78	0.82	0.86	0.89	0.91	1.00

The variation of equivalent conductivity with change in concentration is shown graphically in Fig 7.

Nitrobenzol.

This solvent was purified by fractional distillation. Trimethyl-para-tolyl-ammonium iodide was fairly soluble in nitrobenzol, the solutions possessing a yellow color. The conductivity of the solute in this solvent was measured at 25° and 18°, the results obtained being recorded in Table XVI.

TABLE XVI.

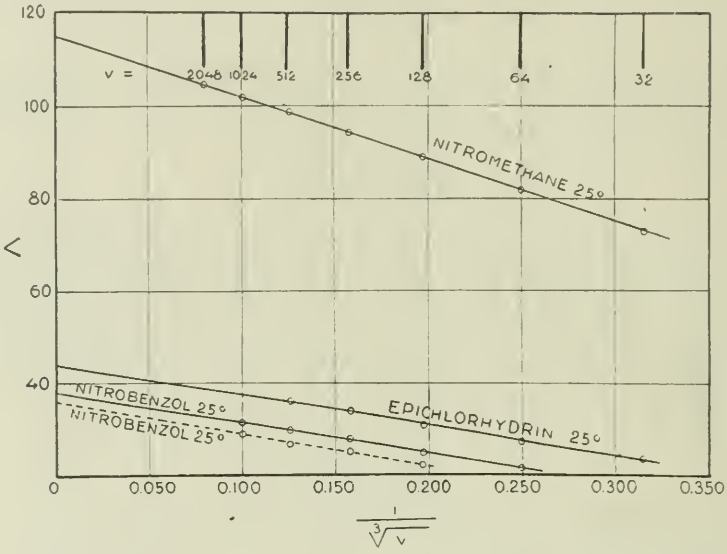
$\kappa_{25} = 0.327 \times 10^{-6}$.

$t = 25°$ $v =$	64	128	256	512	1024	∞
$\kappa' \times 10^4 =$	3.405	1.969	1.096	0.5865	0.3103	
$\Lambda =$	21.77	25.16	27.98	29.86	31.39	
$\Lambda_\infty =$	38.2	38.9	37.1	37.2		38
$\alpha =$	0.57	0.66	0.74	0.79	0.83	1.00
$t = 18°$	$\kappa_{18} = 0.201 \times 10^{-6}$.					
$\kappa' \times 10^4 =$	2.991	1.752	0.989	0.5315	0.2858	
$\Lambda =$	19.13	22.40	25.27	27.11	29.06	
$\Lambda_\infty =$	35.0	36.4	34.2	36.5		36
$\alpha =$	0.53	0.62	0.70	0.75	0.80	1.00
$c_{18-25} =$	0.0197	0.0176	0.0153	0.0145	0.0115	

The change in equivalent conductivity with variation in concentration, for the two temperatures, is shown graphically in Fig. 7. It will be observed that the curves are not parallel, but that they slope towards one another as the concentration decreases, as would be expected from the decrease in the value of the temperature coefficient with decrease in concentration.

For a given dilution it will be observed that the degree of dissociation of trimethyl-para-tolyl-ammonium iodide is considerably greater in the aliphatic than in the aromatic solvent. While the dielectric constant of the former solvent is greater than that of the latter, according to Trouton's rule nitromethane is associated, since its constant is 18.7 instead of 20.65, while, on the other hand, nitrobenzol is not polymerized, since its constant has the value 20.7.

FIG. 7.



VIII. EPICHLORHYDRIN.

As only a very limited quantity of this solvent was obtainable, no attempt was made to purify it. Its low specific conductivity indicated, however, that it was very pure. Trimethyl-para-tolyl-ammonium iodide was found to be very readily soluble in epichlorhydrin, the solutions being of a pale yellow color. In Table XVII are recorded the results of conductivity measurements at 25°.

TABLE XVII.

$\kappa_{25} = 5.367 \times 10^{-7}$.

$t = 25°$ $v =$	16	32	64	128	256	512	∞
$\kappa' \times 10^3 =$	1.255	0.7316	0.4222	0.2392	0.1332	0.0703	
$\Lambda =$	20.08	23.41	27.02	30.62	34.10	35.99	
$\Lambda_\infty =$	. .	40.9	44.4	47.5	43.3		44
$\alpha =$	0.46	0.53	0.62	0.70	0.78	0.82	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 7.

SUMMARY AND CONCLUSIONS.

1. The conductivity of trimethyl-para-tolyl-ammonium iodide in water and in 13 organic solvents has been measured at 25°. In the case of a few of the solvents, measurements have also been made at a second temperature, and the temperature coefficient of the equivalent conductivity of the solute determined.

2. Like the majority of strong electrolytes, it has been found that trimethyl-para-tolyl-ammonium iodide in aqueous solutions does not follow Ostwald's dilution law. Of the several empirical dilution formulæ investigated, only in the case of Storch's general equation,

$$\frac{\alpha^n}{(1-\alpha)v^{n-1}} = k,$$

has a value been obtained for k which does not vary with the concentration of the solute.

3. The conductance of the trimethyl-para-tolyl-ammonium ion in aqueous solution has been found to be 40.3 at 25°.

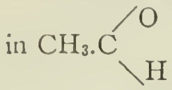
4. The equivalent conductivity at infinite dilution, Λ_∞, of trimethyl-para-tolyl-ammonium iodide in the different solvents has been determined by calculation or extrapolation. The values obtained vary from $\Lambda_\infty^{25} = 13$ for anisaldehyde to $\Lambda_\infty^{25} = 188$ for acetone. The magnitude of these values bears a relation to the chemical constitution of the solvent; and it may be stated, generally, that the equivalent conductivity at infinite dilution of the electrolyte, and, therefore, the velocity of its ions, is greater in an aliphatic solvent than in the corresponding aromatic solvent:

	Λ_∞^{25}	
Nitromethane,	115	Nitro-Compounds.
Nitrobenzol,	38	
Propionitrile,	143	Nitriles.
Benzonitrile,	54	
Propionaldehyde,	120	Aldehydes.
Benzaldehyde,	33	

Moreover, for any homologous series, the value for Λ_∞ is greater the nearer the solvent stands to the beginning of the series:

	Λ_∞^{25}	
(Water),	116	Alcohols.
Methyl alcohol,	100	
Ethyl alcohol,	48	
Formic acid,	90	Acids.
Acetic acid,	25	

Of the various substituting groups, the influence of the aldehyde group on the magnitude of Λ_∞ is greatest,[41] while that of the carboxyl group is least:



$$\text{in } CH_3.C\begin{matrix}/O\\ \backslash H\end{matrix} > CH_3.NO_2 > CH_3.OH > CH_3.CO_2H$$

$$\Lambda_\infty^{25} = 188 > 115 > 100 > 25$$

Department of Chemistry,
Swarthmore College,
September 16, 1918.

Testing for Fires in Piles of Stored Coal. H. H. Stoek. (Western Society of Engineers through *Electrical World*, vol. 72, No. 4, p. 162, July 27, 1918.)—According to Professor Parr of the University of Illinois, bituminous coal can be stored without appreciable loss of heat value, provided that the temperature is not allowed to rise above 180° Fahr. How close to this temperature a pile should be allowed to heat is largely a matter of judgment, for if the rise appears to be decreasing rapidly, it may be safe to allow it to approach 180° Fahr., whereas if the rise is steady and regular it is wise to load out the pile before the danger point is reached. The time also depends upon the means available for loading out the coal. In a plant equipped with large grab buckets and means for rapidly handling the coal, a higher temperature can be permitted than where a considerable time may be required to load out the coal.

A person in charge of a certain kind of coal under certain climatic conditions will learn where the danger point is, and it is impossible to set any critical temperature that will apply to all coals under varying storage conditions. The only safe rule is to watch the pile closely and get ready to load out the coal when the temperature reaches 150° Fahr. and to move the coal if the temperature reaches 175° Fahr. Common methods for testing coal piles for heat are as follows: Watching when the pile begins to steam; observing the odor, which is that of either burning bituminous matter or burning sulphur; inserting an iron rod into the pile and when drawn out testing it with the hand; inserting a thermometer into a pipe driven in the pile; observing spots of melted snow on the pile.

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[41] Walden has shown that the influence of the cyanogen group on the magnitude of Λ_∞ is even more marked than that of the aldehyde group.

A NEW THEORY OF PLATE SPRINGS.*

BY

DAVID LANDAU and PERCY H. PARR.

PAPER 2.

In our first paper[1] we made a liberal effort to show the fundamental principles underlying our new theory of plate springs, and to indicate briefly, though succinctly, the irrationality of the old theory. No direct mathematical proof was offered to substantiate our statements regarding the errors of the old theory for it seemed to us that such proof was not demanded; the facts themselves, as marshalled into evidence, being deemed to be, as the lawyers say, *prima facie* evidence of its inaccuracy.

The reader who has followed our exposition with sufficient care will, however, doubtless find some objections and be inclined to take exception to some of the statements as not having been proved; this may be the case, to an even greater degree, with the engineer who has had much experience in the use of plate springs and especially to him who has kept a record, or compiled statistics, of the breakages of spring plates.

Our intention in the first paper was to avoid tediousness in the exposition of this apparently simple but really very complex subject, hence, it was, in some ways, but a foreword to this more complete and prolix exposition. Much, necessarily, had to be left to the present paper; even this one will not include all of the many elements that have to be considered, certain of which must be left for the third and (for the present) concluding paper. We shall preamble the present exposition by a few remarks which have been verified by tests and experience.

Most experienced spring makers have noticed that the short plate is the one which breaks most often on ordinary plate springs; so far then our theory has offered an intelligible—and as we hope to show, ultimately, a true—explanation of the observed facts. On the other hand, there are many exceptions to this breakage of the short leaf. It is a fact beyond contradiction, that with very many springs, other plates break with equal or, in some rare cases, with even greater frequency than do the short plates. For instance, in a series of endurance tests of several hundreds of springs, made a few years ago, the majority of the breakages occurred in the master leaves; in several cases the intermediate leaves broke, but only in a comparatively small number of cases was the fracture confined to the short leaf. Why should this be so? Indeed, from the exposition of our theory, as given so far, it might be reasonably asked, "If your theory is correct, how is it possible that any plate other than the short one can break first?"

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* Communicated by the Authors.

[1] This Journal, Vol. 185, April, 1918, p. 481.

It may also be mentioned as an established fact that many commercial springs, constructed from the point of view of low cost of production combined with reasonable safety in use, are made of ordinary qualities of "carbon spring steel" except for the master leaves, which are made of high-grade "alloy spring steels."

Why this practice if the theory we have so far expounded be correct? And how can we, on the basis of our theory, account for the many apparent exceptions to it? The answers to these questions are fairly simple, but the formal proofs are tedious and long.

In order to allay the desire of the reader to understand the reasons of the apparent—and they are only apparent—discrepancies between our theory and the facts of practice, we shall give a brief "word-picture" first and afterwards proceed to the formal mathematical proof.

There are two principal causes which operate to induce a leaf, in a leaf spring, other than the short one to break first: for the moment we shall name only one of these and that is *the tapering of the ends of the leaves.*

This one cause—*tapering*—produces the most astonishing modifications in the reactions and, of course, the stresses in the leaves. The "life" of the spring is increased or decreased in proportion as this seemingly minor, but really most important, detail is given proper consideration in the design and in the manufacture. Our theoretical investigations and long practical experience justifies our making immediately the definite statement that, *next to the homogeneity of the molecular structure of the finished product, the tapering of the ends of the leaves is of the greatest importance, and in order to obtain the best results in the* *longevity of a plate spring the tapering should be carried out with mathematical exactitude.*

We believe that we have, in a very great measure, solved this most important question of tapering on scientific principles, and our researches appear to prove that we have been the first to define the precise effects of tapering and its resultant effect on the strength and life of leaf springs.

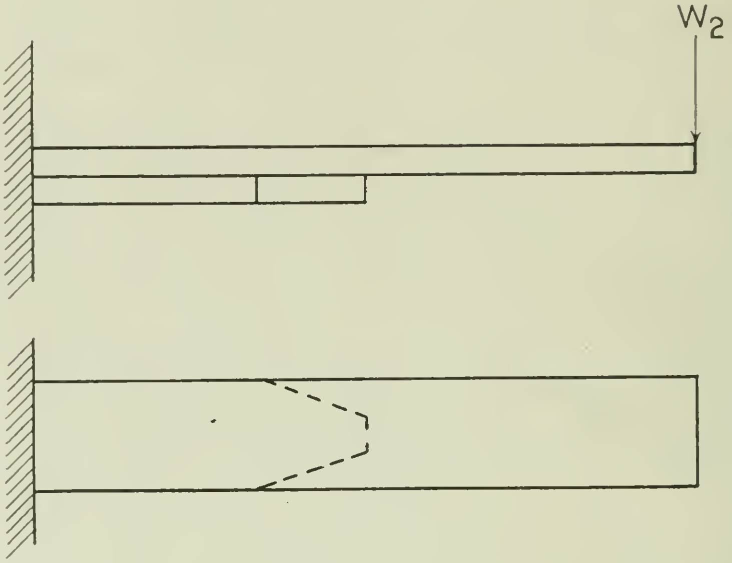
Before the publication of the present paper, if anyone had made an inquiry of the engineer, or even of the experienced spring maker, as to what was the effect of tapering the ends of the leaves on the "strength," the "life" or on the "endurance" of a spring, the average answer would have been about as follows: "The tapered-end leaves look better, but are of no particular advantage;" and as confirmatory evidence, if that be needed, "the railroad springs are scarcely ever tapered." A more astute engineer might "guess" that, "the tapered-end leaf is better," but as to why, how, and how much better? he could give no answer. We shall, in fact, show later on that the effect of tapering may be either for the better or for the worse—the good effects produced have limitations, although, in general, tapering is beneficial as compared to no tapering. The mathematical proof is rigorous but not too easy, and an attempt will first be made to give a mental concept of the physical effects.

Let us consider, for example, Fig. 10; this is the same as Fig. 3, with the exception that the short leaf is tapered in the plane of the width (for illustrative convenience only we have shown the most simple taper). Now, it is clear that with any given load placed on the end of the short leaf, it will deflect more than it would if it were not tapered. This is a simple and obvious fact which does not seem to require a formal proof but which is of the greatest importance. In other words, the effect of tapering the end of a leaf is to make that leaf, as a whole, more flexible; also, since the leaf still has the same section at the point of maximum stress, namely at the point of encastrèment, the safe load that may be placed thereon still remains W_1, although this load will cause a greater deflection of the short leaf than in the case of a non-tapered leaf. This being granted, we may next consider the effects on the leaf above.

Since the load, W_1, on the end of the short leaf (for convenience it may be taken as the load producing the maximum allowed stress in that leaf) can only come from the pressure of the plate above on it, it follows therefore that the plate above must also deflect a greater distance when the bottom plate is tapered than when it is not. But, in order to obtain this greater deflection of the plate above we must place a load, W_2, on it which is greater than it was in the cases of the non-tapered bottom leaf shown in Figs. 8 and 9.

Some readers may take exception to the statement that the load W_2 becomes greater in this case; their judgment is not to be questioned here, but we ask them to withhold any contrary opinion until we give the more rigid proof; we ask them to accept, provisionally, our statement that W_2 is greater when the bottom plate, No. 1, is tapered than when it is not. On this basis we will continue further.

FIG. 10.

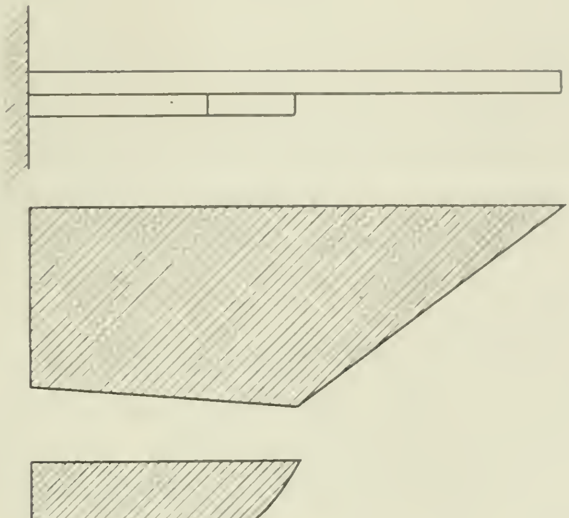


Assuming then that W_2 has now become greater than 4/5 W_1 (the value found in our first paper) we see that we have the apparently curious result that *when we taper the end of the leaf below we can increase the safe load on the leaf above,* and, of course, on the spring as a whole—a result that would hardly be expected, much less looked for. This concludes, briefly, the "word-picture" of the principles in question and of which the formal proofs will be given shortly.

To avoid misunderstanding in future expositions concerning tapered-end leaf springs it is to be understood that we use the word *taper* in its most general sense, except in cases where it is specifically given a limited meaning. A taper, straight or curved, in width only, as in Fig. 10, or a taper in thickness, or any combination of the two, may be assumed to apply with equal force to the discussion.

It seems to us, as the result of our experience of teaching some of these principles to others, that clarity of the mathematical exposition may be gained, and greater confidence placed in the formal reasoning if we place some additional physical illustrations before the reader. Realizing, as we do, the difficulties we had in the earlier years of this investigation, we are prone to expand somewhat our illustrations in order to avoid later dilation. The reader who is so fortunate as to have already obtained a clear mental grasp of our general ideas may skip the next few paragraphs.

FIG. 11.



Consider again Fig. 10; we have stated that W_2, in this case, is greater than the corresponding W_2 of Fig. 3 for the same value of W_1; suppose then that W_2 instead of being equal to $4/5W_1$, as was the case for Fig. 3, is now equal to, say $9/10W_1$, and let us see what happens to the stress distribution in the two plates. The result of this assumption is shown in Fig. 11, which is to the same scale as Fig. 8, in which we showed the stress distribution for the two-leaf spring of Fig. 3. The most important result is that the stress in the main, or master leaf, has increased, by about 6 per cent. on an average, and so the metal in this leaf, which is still not stressed as high as that in the short leaf, is, however, being used to much greater advantage. The stress in the short leaf has been increased slightly, in the tapered part, but the difference here is not of great account; at the same time, it is all in the direction of greater load capacity per unit weight of spring; the weight of metal has been reduced, and that which has been left is utilized to greater advantage. The whole effect then may be said to be:

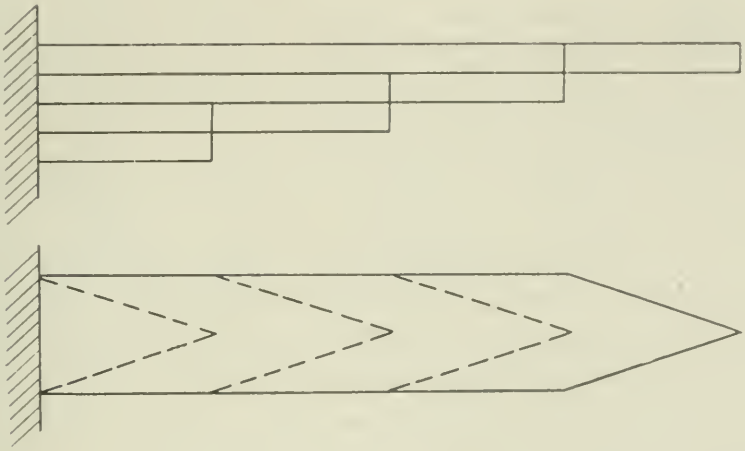
If, in any spring, the "plate below" is tapered in any of the well-known ways, the stress in the "plate above" is increased and, therefore, within certain limits (to be defined later), the safe load on the spring as a whole may be increased.

Our investigations of the history of the theory of plate springs given in our first paper indicate that this very important effect (tapering) has never seriously been considered by any previous investigators.

We have used the terms "plate below" and "plate above"; it seems opportune to define here the sense in which we always use these terms before proceeding further. Any plate in a spring may be taken as the *datum* plate for particular purposes, in which case any shorter plate may be called the "plate below" and any longer plate, the "plate above": thus in a two-plate spring, the short plate is the "plate below" and the long or master plate, the "plate above."

We have already seen that with any plate spring composed of non-tapered plates of equal cross section, the stresses in the upper plates are less than those in the lower ones, and we have just shown that the effect of tapering the ends of the lower leaves is to increase the stresses in the upper ones. The question naturally follows—is it possible so to arrange the tapers that the reactions and stresses shall all be equal? The answer is in the affirmative. A spring having these characteristics can be constructed, and is shown in Fig. 12, which really is none other than that of Fig. A of our Historical Introduction. This is the special spring regarding which all of the old and ordinary formulæ are based, but it is never, or at least very rarely, found in practice. It will be shown later that such a spring made of equal thickness plates and in which the tapers are so made that the moment of inertia is everywhere proportional to the bending moment in the overlap or step, has equal reactions and the stresses are everywhere the same. Theoretically this should be the ideal spring, as it would then carry a load directly proportional to the number of plates; there are other modifying circumstances, however, which will be duly discussed, that prohibit such springs from carrying loads directly proportional to the number of leaves, and such springs, in consequence, are not to be found in general use.

Fig. 12.



Before closing the general description of the physical effects of tapering the ends of the leaves we must push the question a little further and ask: *what is the effect of tapering the plates too much?* The answer is, as we shall prove in due course, that the reactions go on increasing and, after a certain limiting amount of taper, any further tapering will cause the stresses to be greater in the upper leaves than in the lower ones. Since it is usually, from a practical point of view, most important that the master leaf of a spring should not be the first one to fracture, it follows that an excessive amount of tapering is most objectionable. It appears also that the exact details of the tapering are of the utmost importance, and while this is a question which has been altogether neglected from the scientific point of view up to the present, it is necessary to study it with the greatest care in order to obtain the best springs, and it is mainly through the study of this major detail that we have been able to obtain some of the results indicated in our first paper.

The physical illustrations of the effects of tapering the ends of the leaves can no longer be dealt with by exemplifications and analogy; they would soon grow so complex as to become unintelligible. The following mathematical exposition will clarify the situation.

THE GENERAL THEORY OF LEAF SPRINGS.

Had we followed the usual sequence, the general theory of leaf springs, of which the larger part of the present paper is an exposition, would have been treated in our first paper, but, for reasons already stated the actual complexity of this apparently simple subject indicated that it would be advisable for us to discard custom in order to gain clarity, hence our first paper was written so as to give the reader greater confidence in the mathematical generalizations which follow.

If a leaf spring be so constructed that each leaf is in contact with its adjacent one along its entire length, but without pressure—when in the unloaded, or "free" condition—then, on the application of a load, one of three things may happen. First, the leaves may separate everywhere except at the tips and at the centre point of encastrèment; second, the leaves may continue in contact everywhere but without pressure except at the tips; and third, the leaves may tend to foul one into another, so that there will be pressure acting between the leaves for a greater or lesser part of their length.

Our first paper dealt with the first condition, which is usually of the greatest importance, and a hint was given as to the occasional existence of the other conditions.

The second condition may be considered as the limit of either the first or the third, and so forming the line of demarcation between them.

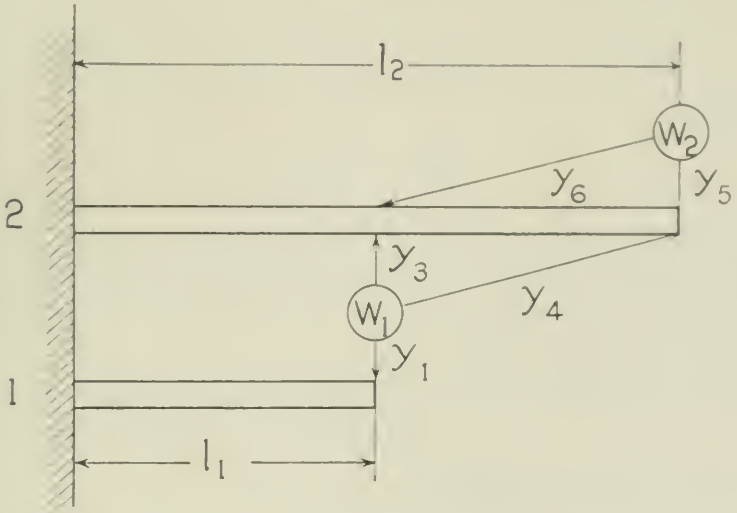
The first case, carefully expounded by the theory given in our first paper, considered the leaves when subjected to load to remain in contact only at the centre point of encastrèment and at the tips of the leaves: most of the commercial springs, especially those of the cheaper grades, and of the heavy springs used by the railways, fall into this class.

The second case will be examined from the point of view of it being the limiting case of the first—it is not of much actual importance, but still requires to be considered in order to make the study complete.

The third case is not of common occurrence in practice, nevertheless it is becoming more so, and may occur either through design or through accidents of manufacture. It is of considerable importance, and will, therefore, be considered in due course.

With these preliminary remarks we now proceed to establish the generalization of our theory in as simple a manner as possible. For convenience we will first consider the two lower plates of a spring.

FIG. 13.



Referring to Fig. 13, the load on the end of plate No. 1, or the reaction between plates Nos. 1 and 2, is W_1. The load on the end of plate No. 2 is W_2.

Considering the bottom plate, No. 1, the load W_1 acting on it will produce a downward deflection which we will denote by y_1, and we may write:

$$y_1 = A_1 W_1$$

where A_1 is a coefficient which may be calculated when we know the section everywhere of plate No. 1.

Now, considering the second plate, the reaction W_1 acting at the distance l_1 will produce an upward deflection, say y_3, at the distance l_1, and we may put:

$$y_3 = A_3 W_1$$

where A_3 is a coefficient which may be calculated when we know the section everywhere of plate No. 2.

Similarly; the load W_2 acting on plate No. 2 at the distance l_2 will produce a downward deflection at l_1 which we may denote by y_6 and we can thus write:

$$y_6 = A_6 W_2$$

where, again, A_6 is a coefficient which may be calculated when we know the particulars of the second plate.

Next, considering the equilibrium of the two plates, it is at once seen that:

$$y_1 = y_6 - y_3$$

or:

$$A_1 W_1 = A_6 W_2 - A_3 W_1$$

from which:

$$\frac{W_1}{W_2} = \frac{A_6}{A_1 + A_3}$$

giving the ratios of the loads or reactions W_1 and W_2.

We must next note that for the second leaf, the reaction W_1 acting at the distance l_1 will produce an upward deflection y_4 at l_2, and we may write:

$$y_4 = A_4 W_1$$

where A_4 may be calculated.

Similarly, the load W_2 acting at l_2 will produce a downward deflection of y_5 at l_2, and we have:

$$y_5 = A_5 W_2$$

where again A_5 is a coefficient which may be calculated.

The total actual deflection then of the two-plate spring at l_2 *due to the load* W_2*, which we shall denote by* Y_2*, is evidently*

$$Y_2 = y_5 - y_4$$

or:

$$Y_2 = A_5 W_2 - A_4 W_1$$

The reasoning, unfortunately, is not too easy, although a careful study of the foregoing, with the aid of the diagram, will show that the question is merely one of equating to equality the upward and downward deflections of the plates, which are produced by the various forces.

Having indicated the method of procedure as applied to the two bottom leaves, we proceed to the general case, and for this we refer to Fig. 14. It is to be understood that the y's (small y's) refer to the deflections of the individual plates, considered apart from the spring as a whole, and the Y's (capital Y's) refer to the deflection of the "partial springs," thus:

y_{4n} is the upward deflection of the $n+1$th leaf at l_{n+1} due to the reaction W_n at l_n;

y_{4n-1} is the upward deflection of the $n+1$th leaf at l_n due to the reaction W_n at l_n;

y_{4n-2} is the downward deflection of the nth leaf at l_{n-1} due to the reaction W_n at l_n;

y_{4n-3} is the downward deflection of the nth leaf at l_n due to the reaction W_n at l_n;

Y_n is the downward deflection of the partial spring of n plates at l_n due to the reaction W_r at l_n.

Now let:

$$y_{4n-a} = A_{4n-a} W_n \quad \ldots\ldots (9)$$

$$Y_n = B_n W_n \quad \ldots\ldots (10)$$

and

$$W_{n-1} = C_{n-1} W_n \quad \ldots\ldots (11)$$

then a consideration of the equality of the deflection of the plates at the points of contact shows that:

$$y_{4n-2} - y_{4n-5} = Y_{n-1}$$

or:

$$A_{4n-2} W_n - A_{4n-5} W_{n-1} = B_{n-1} W_{n-1}$$

from which we obtain:

$$\frac{W_{n-1}}{W_n} = C_{n-1} = \frac{A_{4n-2}}{B_{n-1} + A_{4n-5}} \quad \ldots\ldots (12)$$

We also note that:

$$y_{4n-3} - y_{4n-4} = Y_n$$

or:

$$A_{4n-3} W_n - A_{4n-4} W_{n-1} = B_n W_n$$

from which:

$$B_n = A_{4n-3} - A_{4n-4} C_{n-1} \quad \ldots\ldots (13)$$

and these equations give the fundamental relations between the deflections of the individual leaves, those of the partial (and complete) springs, and the ratios of the various reactions.

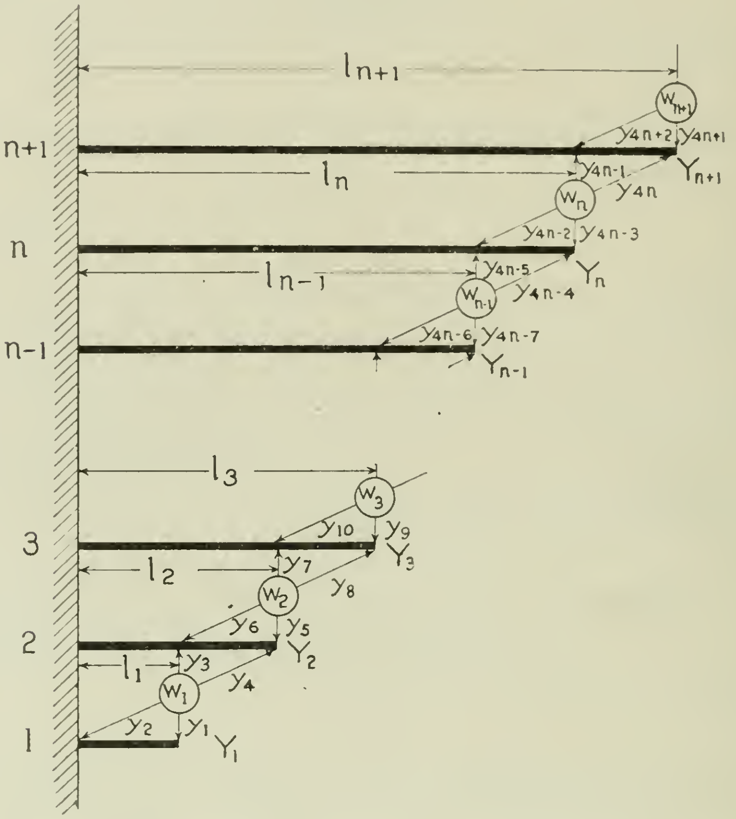
It must be noticed that A_2 (the deflection coefficient for the bottom plate at the encastrèment) is always zero, and that B_1

(the deflection coefficient of the partial spring of one plate only) is always equal to A_1.

The complete relations of a spring can now be calculated, starting at the short plate, called No. 1, and working upwards, as is explained more fully in the succeeding paragraphs.

The A's can all be calculated independently, for they depend solely on the individual details of the various plates: these calculations for various cross-sectional variations of the plates will be dealt with fully in a later section of this paper, and for the moment we will assume that all the A's have been determined.

Fig. 14.



Note that $B_1 = A_1$.

Next put $n = 2$ in equation (12) and we obtain:

$$C_1 = \frac{A_6}{B_1 + A_8}$$

from which C_1 can be calculated.

Then put $n = 2$ in equation (13) and we obtain:

$$B_2 = A_5 - A_4 C_1$$

from which B_2 can be calculated.

Having now calculated C_1 and B_2, put $n = 3$ in equations (12) and (13), giving:

$$C_2 = \frac{A_{10}}{B_2 + A_7}$$

and

$$B_3 = A_9 - A_8 C_2$$

from which C_2 and B_3 are obtained.

Proceeding in a similar manner will give the deflection and reaction coefficients for the complete spring. The work is somewhat tedious but not difficult and, after a few springs have been calculated out, it will easily be seen that the work of arithmetical computation can be systematized so as to minimize the actual amount of labor. It must be admitted, however, that the labor of working out completely, say, a ten-plate "graded"* spring is very considerable, and in practice, where many springs have to be calculated out, a calculating machine is certainly a desirability—almost a necessity.

The above exposition contains the complete theory of the deflection and reaction relations for all leaf springs which are such that the leaves do not tend to foul into one another, and therefore covers, as previously mentioned, the great majority of commercial springs.

We now proceed to details and show how the values for the A's for the various plates are to be derived.

In general terms, if y is the deflection at the distance x from the point of encastrément, then using the well-known relation:

$$\frac{d^2y}{dx^2} = \frac{M}{EI} \quad \ldots\ldots (14)$$

we have:

$$E\frac{dy}{dx} = \int_0^x \frac{M}{I}\,dx \quad \ldots\ldots (15)$$

$$E\,y = \int_0^x \int_0^x \frac{M}{I}\,dx\,dx \quad \ldots\ldots (16)$$

and it is seen at once that:

$$\frac{E}{W_n}\,y_{4n-3} = \int_0^{l_n} \int_0^{l_n} \frac{l_n - x}{I_n}\,dx\,dx \quad \ldots\ldots (17)$$

---

* A "graded" spring is one whose leaves are not all of the same thickness.

$$\frac{E}{W_n} y_{4n-2} = \int_0^{l_{n-1}} \int_0^{l_{n-1}} \frac{l_n - x}{I_n} dx\, dx \ldots\ldots (18)$$

$$\frac{E}{W_n} y_{4n-1} = \int_0^{l_n} \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx\, dx \ldots\ldots (19)$$

and also:

$$y_{4n} = y_{4n-1} + (l_{n+1} - l_n) \frac{dy}{dx_{l_n}} \ldots\ldots (20)$$

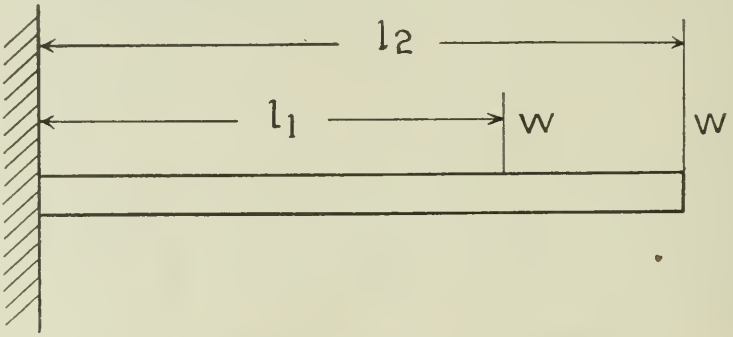
or:

$$\frac{E}{W_n} y_{4n} = \int_0^{l_n} \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx\, dx + (l_{n+1} - l_n) \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx \ldots\ldots (21)$$

No constants are added to the integrals, since both $\frac{dy}{dx}$ and y vanish together with x.

These general relations, as here given, are of course in a somewhat intangible form for practical use; they will be reduced to definite formulæ for particular cases later on, but before doing so, we will prove a very important theorem, which shows that $A_{4n-2} = A_{4n-4}$, so that when A_{4n-4} has been calculated, A_{4n-2} may at once be written down as the same, thus saving twenty-five per cent. of the preliminary work.

FIG. 15.



Theorem: With any cantilever (see Fig. 15) the deflection at l_1 due to a load W at l_2 is equal to the deflection at l_2 due to a load W at l_1.

In general, if the load W is distant l from the point of encastrèment, the bending moment M is $W(l - x)$, and if we put $\frac{1}{I} = f(x)$, where $f(x)$ is any function of x, and apply the standard equation (14), we at once obtain:

$$\frac{E}{W}\frac{d^2y}{dx^2} = l\,f(x) - x\,f(x)$$

$$\frac{E}{W}\frac{dy}{dx} = l\int f(x)\,dx - \int x\,f(x)\,dx$$

say

$$= l\,F(x) - G(x)$$

$$\frac{E}{W}y = l\int F(x)\,dx - \int G(x)\,dx$$

Now integrating the first term by parts, using unity as one factor, and writing *H(x)* for the second term, there results:

$$\frac{E}{W}y = l\left\{ x\,F(x) - \int x\frac{d}{dx}F(x)\,dx \right\} - H(x)$$

$$= l\left\{ x\,F(x) - \int x\,f(x)\,dx \right\} - H(x)$$

$$= l\left\{ x\,F(x) - G(x) \right\} - H(x)$$

Making use of these relations, the deflection at l_1 due to W at l_2 is:

$$l_2\left\{ l_1F(l_1) - G(l_1) \right\} - H(l_1)$$

The deflection at l_2 due to W at l_1 is:

$$l_1\left\{ l_1\,F(l_1) - G(l_1) \right\} - H(l_1) + (l_2 - l_1)\left\{ l_1F(l_1) - G(l_1) \right\}$$

$$= l_2\left\{ l_1\,F(l_1) - G(l_1) \right\} - H(l_1)$$

the same as before; this then proves the theorem.

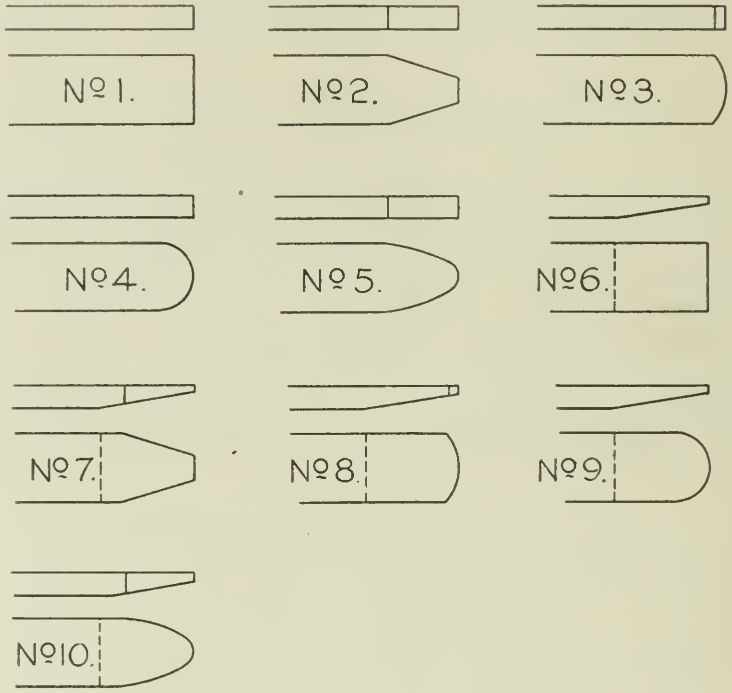
We may now proceed with the evaluation of the fundamental constants, or *A*'s, for plates with various types of ends or points. The most usual types of points are shown by Fig. 16, and the common names of them are as follows:

No. 1. Square, or plain;
No. 2. Trimmed, or trapezoidal (trap');
No. 3. Round;
No. 4. Circular;

No. 5. Parabolic, oval, or egg-shaped;
No. 6. Square-tapered, or plain-tapered;
No. 7. Trimmed-tapered, or trapezoidal-tapered;
No. 8. Round-tapered;
No. 9. Circular-tapered;
No. 10. Parabolic-tapered, oval-tapered, or egg-shape-tapered.

There are various other shapes of points in use but those shown in the Fig. 16 are the most common and also the most important. In many cases, the leaves are finished with a slight bevelling of the ends, but this is of no importance from the present point of view as it is merely a matter of appearance.

Fig. 16.



Now proceeding to the calculations the first and simplest case is of course that of:

No. 1 or Square Leaf Point.

For this point the leaves are simply cut off "square" and there is no tapering either in the width or in the thickness.

For this case, which is simply that of a simple cantilever of uniform section and loaded at the end, if l is the length and y

the deflection at the distance x from the point of encastrement, we have:

$$EI \frac{d^2y}{dx^2} = W(l-x) \qquad (22)$$

$$EI \frac{dy}{dx} = W\left(lx - \frac{x^2}{2}\right) \qquad (23)$$

$$EI\ y = W\left(\frac{dx^2}{2} - \frac{x^3}{6}\right) \qquad (24)$$

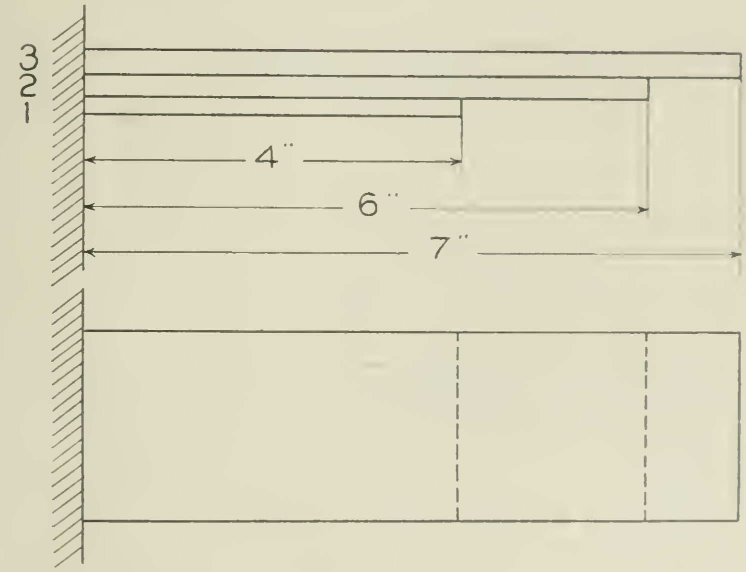
and at the end, when $x = l$, we have

$$EI \frac{dy}{dx} = \frac{Wl^2}{2} \qquad (23a)$$

$$EI\ y = \frac{Wl^3}{3} \qquad (24a)$$

and these relations are all that are necessary in order to make the calculations for a spring with the No. 1 or square points to the leaves.

FIG. 17.



Considering the somewhat extensive abstract work of the preceding, it may now be well to give a practical example, showing the application of the foregoing to a particular concrete case. The spring for which the calculations will be worked out is shown in Fig. 17, for which we will take plate No. 1 as 2" × 3/16" with $I_1 = .001099$ and $Z_1 = .01172$; plate No. 2 as 2" × 7/32" with $I_2 = .001745$ and $Z_2 = .01595$; and plate No. 3 as 2" × 1/4" with $I_3 = .002604$ and $Z_3 = .02084$. E will be taken as $28 \times 10.^6$

Now, in order to calculate the A's we have:

For Plate No. 1.

$$l_1=4,\ I_1=.001099,$$

and

$$y_1=\frac{W_1\times4^3}{3\times28\times10^6\times.001099}=.0006933\ W_1$$

or:

$$A_1=.0006933.$$

A_2 is zero always, as mentioned previously, being only introduced for the sake of symmetry of the mathematical expressions.

For Plate No. 2.

$$l_1=4,\ l_2=6,\ I_2=.001745,$$

and

$$y_3=\frac{W_1\times4^3}{3\times28\times10^6\times.001745}=.0004366\ W_1$$

or

$$A_3=.0004366$$

$$y_4=y_3+(l_2-l_1)\frac{dy}{dx_{l1}}$$

$$=.0004366\ W_1+\frac{2\times W_1\times4^2}{2\times28\times10^6\times.001745}$$

$$=.0004366\ W_1+.0003275 W_1$$

$$=.0007641\ W_1$$

or

$$A_4=0007641.$$

$$y_5=\frac{W_2\times6^3}{3\times28\times10^6\times.001745}=.001473\ W_2$$

or

$$A_5=.001473.$$

From the theorem given above:

$$A_6=A_4=.0007641.$$

For Plate No. 3.

$$l_2=6,\ l_3=7,\ I_3=.002604,$$

and

$$y_7=\frac{W_2\times6^3}{3\times28\times10^6\times.002604}=.0009875\ W_2$$

or

$$A_7=.0009875.$$

$$y_8=y_7+(l_3-l_2)\frac{dy}{dx_{l_2}}$$

$$=.0009875\ W_2+\frac{W_2\times6^2}{2\times28\times10^6\times.002604}$$

$$=.0009875\ W_2+.0002469\ W_2$$

$$=.001234\ W_2$$

or

$$A \quad = .001234$$

$$y_9 = \frac{W_3 \times 7^3}{3 \times 28 \times 10^6 \times .002604} = .001568\ W_3$$

or

$$A_9 = .001568$$

From the theorem:

$$A_{10} = A_8 = .001234.$$

Having now determined the values of all the A's, the B's and C's may readily be found, thus:

$$B_1 = A_1 = .0006933$$

$$C_1 = \frac{A_6}{B_1 + A_3} = \frac{.0007641}{.0006933 + .0004366} = .6763$$

$$B_2 = A_5 - A_4\,C_1 = .001473 - .0007641 \times .6763 = .0009562$$

$$C_2 = \frac{A_{10}}{B_2 + A} = \frac{.001234}{.0009562 + .0009875} = .6349$$

$$B_3 = A_9 - A_8\,C_2 = .001568 - .001234 \times .6349 = .0007845$$

It may be also noted that:

$$W_2 = \frac{W_1}{C_1} = \frac{W_1}{.6763} = 1.479\ W_1$$

and

$$W_3 = \frac{W_2}{C_2} = \frac{1.479 W_1}{.6349} = 2.330\ W_1$$

The strength modulus for bending of plate No. 1 being $Z = .01172$, then if we allow, for convenience of calculation, a maximum stress of 100,000 lbs. per square inch, the safe load W_1 will be $\frac{100000 \times .01172}{4} = 293$ lbs. $W_2 = 293 \times 1.479 = 433$ lbs. and W_3, which is the safe load on the three-leaf cantilever spring, will be $293 \times 2.330 = 683$ lbs. Also, as the deflection is B_3 inches per lb. of W_3, the stiffness of the spring is $\frac{1}{B_3} = 1275$ lbs. load per inch deflection.

The bending moment in plate No. 2, directly over the tip of plate No. 1, is $433 \times 2 = 866$ in. lbs. and as $Z_2 = .01595$ the stress is $866/.01595 = 54{,}290$ lbs. per sq. in. At the centre the bending moment is $433 \times 6 - 293 \times 4 = 1426$ in. lbs. with a stress of 89,400 lbs. per sq. in.

For plate No. 3, the bending moment directly over the tip of plate No. 2 is 683 × 1 = 683 in. lbs. with a stress of 32.770 lbs. per sq. in. and at the centre the bending moment is 683 × 7 − 433 × 6 = 2183 in. lbs. with a stress of 104,750 lbs. per sq. in.

This last result is interesting, as it shows a slightly higher stress in the master leaf than in the short one; as previously mentioned, this is not of common occurrence and cannot occur with a non-graded non-tapered spring, but it may and sometimes does occur with graded and tapered springs. The new theory thus accounts for the observed facts that with some types of springs the short leaf nearly always breaks first, while with other springs —as in the particular case just given—it is the master leaf which is usually the first to fracture. There are, of course, intermediate conditions, when one of the intermediate leaves is most apt to break, but these are few in comparison with the cases of fracture of either the short or the master leaf.

The square-point leaf is in such general use, especially for the heavier grades of springs, that it is desirable to simplify, as much as possible, the calculations for the reactions and deflections of this style of spring. This can be done to a considerable extent in the following manner:

Referring back to the fundamental equation (7), it will be found that this can be rewritten as follows:

$$\frac{2\,W_n\left(\frac{I_{n+1}}{I_n}+1\right)-W_{n-1}\frac{I_{n+1}}{I_n}\left\{\left(\frac{l_{n-1}}{l_n}\right)^3\left(3\,\frac{l_n}{l_{n-1}}-1\right)\right\}}{3\,\frac{l_{n+1}}{l_n}-1}\ldots\ldots\ldots(25)$$

and if we write

$$P_n \text{ for } \frac{I_{n+1}}{I_n},\ Q_n \text{ for } \frac{l_{n+1}}{l_n},\ \text{and } R_{n-1} \text{ for } \frac{3Q_{n-1}-1}{Q^3_{n-1}}$$

we obtain:

$$W_{n+1} = \frac{2\,W_n\,(P_n+1)-W_{n-1}\,P_n\,R_{n-1}}{3\,Q_n-1}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(26)$$

which is a reasonably simple formula for practical manipulation.

In order to facilitate the practical use of this equation (26) we have calculated the values of the function of Q_{n-1} denoted by R_{n-1}, and these are given in Table No. VII.

TABLE VII.

Q_{n-1}	R_{n-1}	Dif.	Q_{n-1}	R_{n-1}	Dif.
1.00	2.0000	297	1.57	.9587	105
1.01	1.9703	291	1.58	.9482	103
1.02	1.9412	285	1.59	.9379	102
1.03	1.9127	280	1.60	.9277	100
1.04	1.8847	274	1.61	.9177	98
1.05	1.8573	269	1.62	.9079	97
1.06	1.8304	264	1.63	.8982	95
1.07	1.8040	258	1.64	.8887	94
1.08	1.7782	253	1.65	.8793	92
1.09	1.7529	249	1.66	.8701	91
1.10	1.7280	243	1.67	.8610	90
1.11	1.7037	239	1.68	.8520	88
1.12	1.6798	234	1.69	.8432	87
1.13	1.6564	230	1.70	.8345	85
1.14	1.6334	225	1.71	.8260	85
1.15	1.6109	221	1.72	.8175	83
1.16	1.5888	216	1.73	.8092	81
1.17	1.5672	213	1.74	.8011	81
1.18	1.5459	208	1.75	.7930	79
1.19	1.5251	205	1.76	.7851	79
1.20	1.5046	200	1.77	.7772	77
1.21	1.4846	197	1.78	.7695	76
1.22	1.4649	193	1.79	.7619	74
1.23	1.4456	190	1.80	.7545	74
1.24	1.4266	186	1.81	.7471	73
1.25	1.4080	183	1.82	.7398	72
1.26	1.3897	179	1.83	.7326	70
1.27	1.3718	176	1.84	.7256	70
1.28	1.3542	173	1.85	.7186	69
1.29	1.3369	169	1.86	.7117	67
1.30	1.3200	167	1.87	.7050	67
1.31	1.3033	163	1.88	.6983	66
1.32	1.2870	161	1.89	.6917	65
1.33	1.2709	158	1.90	.6852	64
1.34	1.2551	155	1.91	.6788	63
1.35	1.2396	152	1.92	.6725	63
1.36	1.2244	149	1.93	.6662	61
1.37	1.2095	147	1.94	.6601	60
1.38	1.1948	144	1.95	.6541	60
1.39	1.1804	142	1.96	.6481	59
1.40	1.1662	140	1.97	.6422	58
1.41	1.1522	136	1.98	.6364	57
1.42	1.1386	135	1.99	.6307	57
1.43	1.1251	132	2.00	.6250	111
1.44	1.1119	130	2.02	.6139	108
1.45	1.0989	128	2.04	.6031	105
1.46	1.0861	126	2.06	.5926	103
1.47	1.0735	124	2.08	.5823	100
1.48	1.0611	121	2.10	.5723	98
1.49	1.0490	120	2.12	.5625	95
1.50	1.0370	117	2.14	.5530	94
1.51	1.0253	116	2.16	.5438	91
1.52	1.0137	113	2.18	.5347	88
1.53	1.0024	112	2.20	.5259	86
1.54	.9912	110	2.22	.5173	84
1.55	.9802	109	2.24	.5089	82
1.56	.9693	106	2.26	.5007	80

TABLE VII.—*Continued.*

Q_{n-1}	R_{n-1}	Dif.	Q_{n-1}	R_{n-1}	Dif.
2.28	.4927	78	2.66	.3709	52
2.30	.4849	76	2.68	.3657	50
2.32	.4773	75	2.70	.3607	49
2.34	.4698	72	2.72	.3558	48
2.36	.4626	72	2.74	.3510	47
2.38	.4554	69	2.76	.3463	47
2.40	.4485	68	2.78	.3416	45
2.42	.4417	66	2.80	.3371	44
2.44	.4351	65	2.82	.3327	44
2.46	.4286	64	2.84	.3283	43
2.48	.4222	62	2.86	.3240	42
2.50	.4160	61	2.88	.3198	41
2.52	.4099	59	2.90	.3157	40
2.54	.4040	58	2.92	.3117	40
2.56	.3982	57	2.94	.3077	39
2.58	.3925	56	2.96	.3038	38
2.60	.3869	55	2.98	.3000	37
2.62	.3814	53	3.00	.2963	
2.64	.3761	52			

In order to show the utility of this equation and table, we will now work out the same spring (Fig. 17) that we have solved above, by this method.

First find the values of the P's and Q's, thus:

$$P_1 = .001754/.001099 = 1.588$$

$$P_2 = .002604/.001745 = 1.492$$

$$Q_1 = 6/4 = 1.500$$

$$Q_2 = 7/6 = 1.167$$

R_1 is to be taken from Table VII, opposite the value of Q_1, or 1.500, where we find $R_1 = 1.0370$. For R_2, corresponding to Q_2, we find 1.5888 as the tabular value corresponding to 1.16, with a first difference of 216 and $216 \times .7 = 151$ which must be *subtracted* from the 1.5888 since R decreases as Q increases, thus giving 1.5737 as the value of R_2.

Next inserting these values in equation (26) and putting $W_1 = 1$ we have, since $W_0 = 0$:

$$W_2 = \frac{2\,(P_1+1)}{3Q_1 - 1} = \frac{2\,(1.588 + 1)}{3 \times 1.5 - 1} = 1.479$$

$$W_3 = \frac{2\,W_2\,(P_2 + 1) - W_1\,P_2\,R_1}{3Q_2 - 1}$$

$$= \frac{2 \times 1.478\,(1.492 + 1) - 1.492 \times 1.037}{3 \times 1.167 - 1} = 2.327$$

these values being almost exactly the same as before—if more figures were taken they would be exactly the same, and in any case the differences are practically negligible.

The same table (VII) can be used for simplifying the deflection calculations, for the deflection coefficient B_n may be written in the form:

$$B_n = \frac{K_n l^3_n}{6 \, EI_n} \quad \text{(27)}$$

where:

$$K_n = 2 - \frac{W_{n-1}}{W_n} R_{n-1} \quad \text{(28)}$$

To apply this to the above case, we have $n = 3$ for the three-plate spring,

$$I_3 = .002604, \; l_3 = 7, \; W_2 = 1.479, \; W_3 = 2.327,$$

$$K_3 = 2 - \frac{W_2 \, R_2}{W_3} = 2 - \frac{1.479 \times 1.5737}{2.327} = .9995$$

and

$$B_3 = \frac{.9995 \times 7^3}{6 \times 28 \times 10^6 \times .002604} = .0007837$$

which is sensibly the same as obtained before. It will easily be seen that this method of calculation greatly reduces the labor of computation in cases where square-point leaves are concerned. For most practical cases where the leaf ends are "trap" points the present formulæ may be used—we shall see that this is the case in the later portion of the present paper.

(To be concluded.)

Jerusalem Has New Water-supply. ANON. (*Engineering News-Record,* vol. 81, No. 20, p. 890, November 14, 1918. Through the *London Surveyor.*)—Following closely upon the occupation of Jerusalem by the British, investigations for a new water-supply were begun by the Royal Engineers. Four days later a scheme was outlined. This was on February 14th but shortage of transportation facilities and bad weather put off the beginning of construction until about the second week in April. On June 18th water was being delivered. The supply is pumped from springs to the city. Many miles of pipe have been laid, and the supply is being delivered directly to hospitals, to "stand-pipes in every quarter of the city" and also to cisterns, the latter on condition that the cisterns be cleaned out to the satisfaction of the water authorities before they are filled. The daily yield of the springs is about 400,000 U. S. gallons. The water consumption of the city is said to be about ten times what it was formerly. It is reported that the "beneficial effects upon the health of the city has been instant and widespread."

Scientific Management versus Its Practical Adaptation. G. S. ANDRASSY (*Machinery*, vol. 25, No. 2, p. 132, October, 1918).—True scientific management is practically nothing but discernment of the obvious: common sense backed by enough education and training to develop ideas into practical results. A reasonably good engineer or accountant is peculiarly fitted by training to succeed in efficiency work, though men of other callings have been very successful in it. The whole theory and profession of scientific management, however, is becoming a subject for jest through the efforts of two types of individuals. The first is the half-trained, self-assertive person with a superabundance of theory, who fails to discern the difference between one business and another, and would apply the same methods to all. He lacks the practical experience necessary to instruct others and is fundamentally unfitted for the work and unable to analyze the small details that make up any action in life. The second is the person with the scientific mind. He has a thirst for knowledge and is willing to spend two dollars gathering details about how a dollar's worth of profit ought to be made. He compiles tables and files any information about all kinds and conditions of business and operations, but in many cases neither details, tables nor information have any practical value, and this management expense goes to the overhead.

Scientific management is overburdened with system and form. The basic facts are good, and nearly any business can be improved by employing a competent man who has nothing else to think or worry about but improvement. A company employing such a man usually expects too much, and, to get the worth of its money, wants to see the outward indications of the changes and improvements looked for. The average business employs people of ordinary intelligence, and practical and profitable change is more a matter of gathering up the loose ends and organizing a system of execution than it is radically changing present methods. If the man called in will stop systematizing and information-gathering when he knows he ought to stop, the business will benefit; but if he feels obliged to continue because more is expected of him, or because he wants to know—because he is half-inventor and wants to see some way of his supersede some other way—or because he merely desires to pose as the expert—then the business will suffer. It is sometimes the quiet, unobtrustive, meek sort of fellows who produce the best results, but it is usually the loud talkers and the installers of much system that get the salary. As money is what most people are after, there are more of the second class of efficiency men than there are of the first.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

Effect of Aldehydes With and Without Fertilizers on Dunkirk Clay Loam.

THE RESULTS OBTAINED.

An experiment to test the action of aldehydes on a third soil in the field was conducted on the Dunkirk clay loam on the experimental farm of the Cornell Experiment Station at Ithaca, N. Y., in 1916.

The soil on which the experiment is laid out is the silty phase of the Dunkirk clay loam. It is stiff and rather compact and runs together, making it difficult to cultivate. The field produces average crops for the section, yet it is a less productive soil than the Hagerstown loam at State College, Pa. Lime benefits the soil for clover, but not especially for grass. When examined in the laboratory the soil was found to be very acid, and its oxidizing power was much less than either the Hagerstown loam or the Arlington soil on which the aldehyde experiments were made.

As in the two former field experiments, cowpeas were grown. The climate is rather cold and the season too short in this section of New York for cowpeas, but, inasmuch as the other field experiments were made with cowpeas, it was desired to grow the same crop in this soil.

The vanillin, salicylic aldehyde, fertilizers, and lime were used in the same amounts as in the former experiments, and the aldehydes and fertilizers were applied in three portions as before. The arrangement of the plots was somewhat different from that of the other experiments. These plots were 10 feet by 6.8 feet—one six-hundred-and-fortieth of an acre—the same size as the Arlington plots. The plan of the experiment and arrangement of the plots is shown in Fig. 68. Three rows of peas were planted in each plot, the rows being 2 feet from the edge of the plot and 4 feet apart. The peas were planted May 29, 1916.

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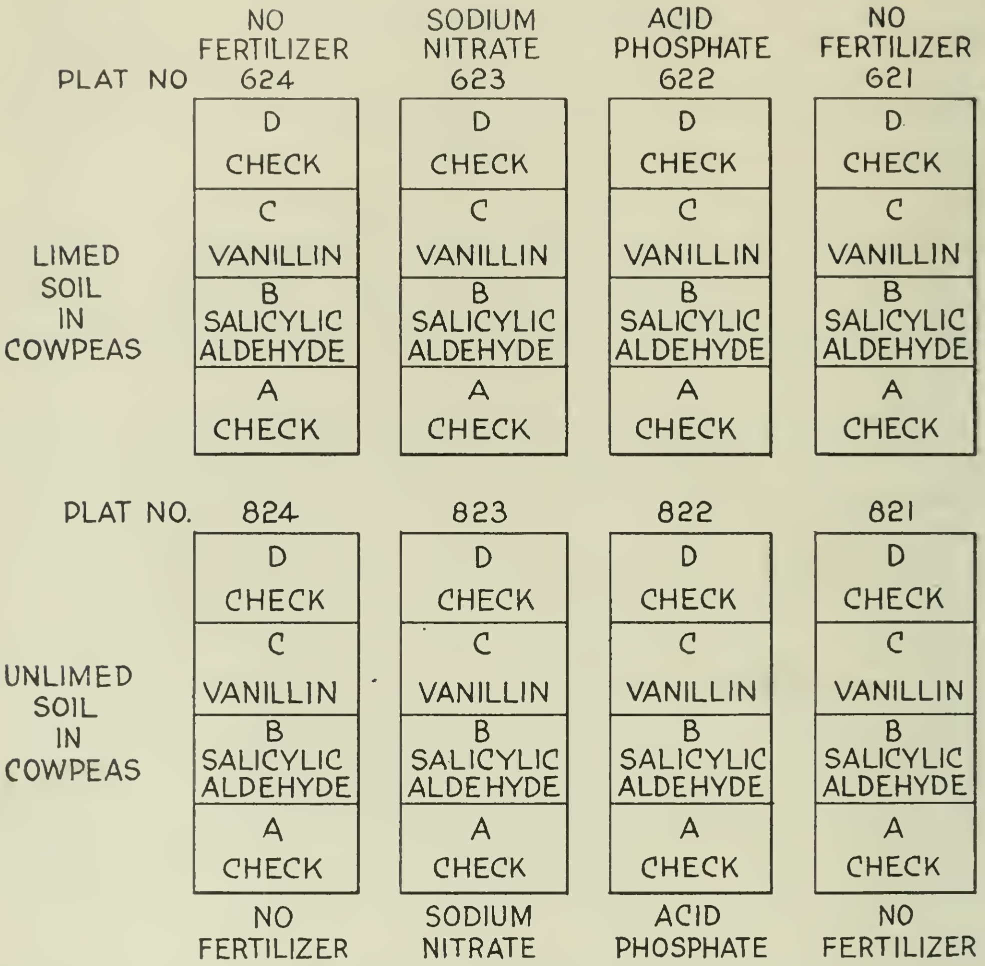
* Concluded from page 584, Vol. 186, November, 1918.

The cowpeas made a poor growth on the entire set of plots; the best did not reach a height of 12 inches. On the unlimed soil the plants on the untreated plots grew to a height of about 8 inches. The effect of the vanillin and salicylic aldehyde was very marked. Germination was affected on the vanillin and salicylic aldehyde plots of the unfertilized, unlimed section; that is, plots No. 621 B and C and No. 624 B and C. A number of these plants died when an inch or two high, and those that survived made a scant growth. The plants on the vanillin and salicylic aldehyde plots, which were fertilized with sodium nitrate and acid

FIG. 68.



	NO FERTILIZER	SODIUM NITRATE	ACID PHOSPHATE	NO FERTILIZER
PLAT NO	624	623	622	621
LIMED SOIL IN COWPEAS	D CHECK	D CHECK	D CHECK	D CHECK
	C VANILLIN	C VANILLIN	C VANILLIN	C VANILLIN
	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE
	A CHECK	A CHECK	A CHECK	A CHECK
PLAT NO.	824	823	822	821
UNLIMED SOIL IN COWPEAS	D CHECK	D CHECK	D CHECK	D CHECK
	C VANILLIN	C VANILLIN	C VANILLIN	C VANILLIN
	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE	B SALICYLIC ALDEHYDE
	A CHECK	A CHECK	A CHECK	A CHECK
	NO FERTILIZER	SODIUM NITRATE	ACID PHOSPHATE	NO FERTILIZER

Plan of the aldehyde fertilizer experiment on the Dunkirk clay loam at the Cornell Experiment Station.

phosphate, grew much better, but in their early stage of growth they were not as good as the plants on the untreated soil.

The aldehydes were not so harmful on the limed soil, yet it was perceptible that the plants were making a slower growth than in the limed soil to which no aldehydes were added. Where the limed soil was fertilized with sodium nitrate and acid phosphate the aldehydes did not appear to be checking growth in the early stage of the plants.

The crop was harvested on September 6. The plants had made their full growth and were in the fruiting stage at this time. The results are given in Table XXI.

TABLE XXI.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas in the Field on Dunkirk Clay Loam, and the Action of Fertilizers in Modifying Their Effects (Weights Given in Pounds Per Plot).

Plot No.	Treatment	Unlimed soil				Plot No.	Limed soil			
		Green weight		Dry weight			Green weight		Dry weight	
		Hay	Relative	Hay	Relative		Hay	Relative	Hay	Relative
	No-fertilizer section:									
821 A	Check	10.7	100	3.2	100	621 A	10.9	100	2.5	100
821 D	Check	10.2		2.6		621 D	9.6		2.7	
821 B	Salicylic aldehyde	1.0	9	0.2	7	621 B	7.4	72	1.7	65
821 C	Vanillin	1.9	18	0.4	14	621 C	8.4	82	2.4	92
	Acid phosphate section:									
822 A	Check	7.1	100	1.8	100	622 A	8.6	100	2.0	100
822 D	Check	6.4		1.5		622 D	11.2		2.6	
822 B	Salicylic aldehyde	5.5	81	1.4	85	622 B	8.6	86	2.0	86
822 C	Vanillin	6.1	90	1.4	85	622 C	8.1	81	2.0	86
	Sodium nitrate section:									
823 A	Check	7.9	100	2.1	100	623 A	10.5	100	2.4	100
823 D	Check	8.1		1.9		623 D	7.6		1.7	
823 B	Salicylic aldehyde	6.5	81	1.6	80	623 B	9.7	107	2.3	112
823 C	Vanillin	6.2	77	1.6	80	623 C	9.1	100	2.6	127
	No-fertilizer section:									
824 A	Check	8.3	100	2.3	100	624 A	8.0	100	1.9	100
824 D	Check	6.6		1.6		624 D	9.1		2.3	
824 B	Salicylic aldehyde	1.8	24	0.4	22	624 B	7.9	92	1.8	86
824 C	Vanillin	2.0	27	0.5	27	624 C	7.1	85	1.7	81

Considering first the unlimed soil, it is seen in the table that the yield from the vanillin and salicylic aldehyde plots of the two unfertilized sections (Plots 821 and 824) is very small as compared with their checks. In the acid phosphate section (Plot 822) salicylic aldehyde reduced green weight from 100, as an average of the two checks, to 81, a reduction of 19 per cent. The vanillin reduced growth from 100 to 90, a reduction of 10 per cent. In dry weight both substances reduced growth from 100 to 85, 15 per cent. In the sodium nitrate section (Plot 823) both compounds reduced the dry weight from 100 to 80, a reduction of 20 per cent. Neither aldehyde had nearly so bad an effect on the fertilized soil as they did on the untreated soil. When the green weight is used as a criterion, acid phosphate had more effect in lessening the harmfulness of vanillin than it did of salicylic aldehyde, which is not altogether in harmony with former results on other soils. Sodium nitrate also lessened the harmfulness of both compounds in this soil, while in other soils sodium nitrate overcame the effect of vanillin, but did not have so marked an effect on salicylic aldehyde.

On the unfertilized limed soil (Plots 621 and 624) both compounds checked growth considerably, but the harmfulness was not so great as on the unlimed soil. This was true to a somewhat less extent on the limed soil to which acid phosphate was added (Plot 622), but on the limed soil to which sodium nitrate was applied (Plot 623) there was no reduction in growth from either vanillin or salicylic aldehyde.

It is apparent from the results that both vanillin and salicylic aldehyde are very harmful in this soil, even more so than in the Arlington soil. The fact that the crop grown, cowpeas, was not suitable for the New York climate may be a factor in the degree of damage which the crop received, yet the results given show undoubtedly that the aldehydes are harmful in this soil, and it will be pointed out later that the aldehydes remained in the soil throughout the growing season. The lime and fertilizer helped the conditions toward betterment of growth, but the aldehydes had their effects even under these conditions.

Effect of Vanillin and Salicylic Aldehyde on the Oxidation of the Soil.

It was pointed out before that the Dunkirk clay loam has a poor oxidizing power. The Arlington soil had about three times the oxidizing power and the Hagerstown loam about five times that of the Dunkirk soil. The oxidation power of the soil in the plots made on samples taken near the end of the growing season is given in Table XXII. The oxidation of the untreated soil is taken as 100.

TABLE XXII.

Effect of Aldehydes and Fertilizers on the Oxidation Power of Dunkirk Silty Clay Loam.

Treatment	Plot No.	Relative oxidation unlimed soil	Plot No.	Relative oxidation limed soil
Untreated plot	821 A	100		
Vanillin	821 C	51	621 C	97
Vanillin	824 C	82	624 C	125
Vanillin, acid phosphate	822 C	250	622 C	125
Vanillin, sodium nitrate	823 C	230	623 C	125
Salicylic aldehyde	821 B	90	621 B	105
Salicylic aldehyde	824 B	84	624 B	95
Salicylic aldehyde, acid phosphate	822 B	127	622 B	120
Salicylic aldehyde, sodium nitrate	823 B	125	623 B	122

The addition of vanillin and salicylic aldehyde to this soil, already weak in its oxidizing power, still further reduced this function of the soil. The vanillin in one plot on the unlimed, unfertilized soil reduced the oxidation from 100 for the untreated soil to 51, and in the second plot from 100 to 82. The salicylic aldehyde in one plot reduced the oxidation from 100 for the untreated plot to 90, and in the other from 100 to 84. The plots to which the aldehydes were added together with sodium nitrate or acid phosphate had a stronger oxidizing power than the untreated soil, showing that the fertilizers had stimulated oxidation even in the presence of the aldehydes which tend to check this function in a weak soil. Liming the soil also produced an effect on its oxidizing power, but the results do not show clearly that it has aided materially, as did the fertilizers. The action of fertilizers and lime in overcoming the retarding effect of aldehydes in soil oxidation is again in harmony with the effect of fertilizers and lime in ameliorating their harmfulness in growth.

Examination of Soils for Aldehydes at the End of the Growing Season.

Samples of soil were taken from each plot at the time the crop was harvested in order to determine whether or not the aldehyde had remained in the soil as such throughout the growing season. Thirty pounds of soil from each plot was subjected to the method for the isolation of aldehydes. The odor of vanillin could be detected in the soil all during the season, and it was faintly perceptible even at the time the crop was harvested.

Aldehydes were found to be present in each of the unfertilized plots (Nos. 821 C and 824 C) on the unlimed soil to which vanillin had been added. It was found also in both of the unfertilized plots on the unlimed soil to which salicylic aldehyde was added (Nos. 821 B and 824 B).

Aldehydes were also found in the plot fertilized with sodium nitrate to which vanillin was added (No. 823 C), but none was found in the vanillin plot (No. 822 C) fertilized with acid phosphate.

The salicylic aldehyde plot (No. 823 B) fertilized with sodium nitrate did not show the presence of aldehyde, while the salicylic aldehyde plot fertilized with acid phosphate (No. 822 B) was found to contain the aldehyde material.

Of the limed soils only two plots were found to contain aldehyde material. These were plots Nos. 621 B and 624 B, the unfertilized plots to which salicylic aldehyde had been added. No aldehydes could be isolated from any of the other plots.

The results of the analysis of the soil show that the aldehydes remained in most of the unlimed plots throughout the growing season. Out of the eight plots on the unlimed soil to which vanillin and salicylic aldehyde were added six were found to contain the aldehydes, and in two no aldehydes could be isolated. In each of the unfertilized plots to which vanillin and salicylic aldehyde were added, the plots which made the poorest growth, the aldehydes were found to remain in the soil.

The experiment on the Dunkirk clay loam again demonstrates that if the aldehydes are not destroyed in the soil they will have detrimental effect on the crop growing therein. Davidson (16), who worked with the Dunkirk clay loam in pots holding three gallons of soil, found that vanillin used in amounts of 1000 parts per million reduced the production of grain and straw of wheat 10.3 per cent. on unfertilized soil. With 500 and 100 parts per million there was no decreased growth. On limed soil 1000 parts per million reduced growth 21 per cent., and 500 parts per million 14 per cent. It is rather surprising that the vanillin should be more harmful in his experiment on limed soil, as in all controlled experiments with vanillin it has been found to be changed in a limed soil. The vanillin was not as harmful in his tests when the soil was fertilized with phosphoric acid. This is somewhat in harmony with the field experiments reported in this paper, where it is shown that the vanillin was not as harmful when fertilized with acid phosphate, and it is interesting also to note that the aldehydes had disappeared from this plot when examined at the end of the crop season. It is unfortunate that Davidson did not determine this point in his work. The irregularities in growth under the different fertilization treatments might have been explained had he determined whether the added vanillin remained in his differently treated cultures or whether it was destroyed. On account of the wide variations in the chemical and biological nature of different soils, or of the same soil when kept under different conditions, it seems unsafe to draw conclusions as to the behavior of added organic substances in soils without determining whether or not the added substance remains as such in the soil.

From the results of the field experiments it is seen that the added salicylic aldehyde and vanillin are harmful in this soil, and that the added aldehydes remained in the soils at least throughout the growing season. The soil is shown to have a low oxidizing power, which is lessened by the additions of aldehydes and is increased by the application of fertilizers.

Summary of the Results of Field Experiments With Aldehydes.

Field experiments with salicylic aldehyde and vanillin were made on three soils, each being of a different geological origin, having different chemical and biological characteristics, different crop-producing powers, and situated in widely different geographical locations.

Both aldehydes persisted and were harmful in two of the soils, and were destroyed and consequently were not harmful in the third.

The two soils in which the aldehydes persisted are acid soils, having weak oxidizing activities and lower crop-producing powers than the soil in which the aldehydes disappeared. The soil on which the aldehydes were destroyed and produced no harmful effect on crops is a limestone soil, with strong biological activities and good crop-producing powers.

The aldehydes did not long remain as such in the two soils when limed, and their harmfulness in the limed soil was greatly lessened. Fertilizers have an effect on the physiological action of both aldehydes. The effects of salicylic aldehyde were partially overcome by acid phosphate and that of vanillin by sodium nitrate, which is in harmony with the action of these salts on the aldehydes in nutrient-culture solutions.

THE ELIMINATION OF ALDEHYDES FROM FIELD SOILS BY SOIL TREATMENT.

The experiments thus far presented deal with the effects of added aldehyde in soils. Evidence has been secured to show that with a rational fertilizer treatment the added aldehydes lose their harmfulness and are even destroyed by biological activities induced by fertilizer application. The next step in the investigation is a study of a soil in which salicylic aldehyde was formed by Nature therein and has remained or continued to be formed for at least four years. The investigation of this soil has substantiated the results thus far secured in the experiments where the aldehydes were added, and has made it possible to suggest treatments to remedy the unfertility of a soil, where this unfertility is due to the presence of harmful aldehydes.

Experiments on Mount Vernon Garden Soils.

In an investigation of the soils of the Mount Vernon estate, Virginia, the historic home of George Washington, a study was made of the organic constituents of the soils of the flower gardens. When subjected to the methods for isolating organic substances from soils, devised in the Laboratory of Soil Fertility Investigations, saccharic acid, acrylic acid, mannite, and salicylic aldehyde were found. Of these, compound salicylic aldehyde has proved the most interesting, and, as it has been found to have considerable influence on plants, this study is concerned with it principally.

The soil of the flower garden is a brown mellow loam containing enough sand and vegetable matter to effect an excellent structural condition. At a depth of about 15 inches the surface soil passes into a reddish-brown to yellowish-brown clay loam. This subsoil in turn grades into a compact red clay, faintly mottled in places with grayish colors, at a depth of approximately 24 inches. This layer of material resembles a hard-pan formation. This compact condition undoubtedly affects the movement of moisture and air. The examination of the soil in the laboratory showed that the surface soil was acid and the subsoil decidedly so.

Box hedges, roses, and violets have grown in the gardens for over a century; in fact, the original plan of the garden as inaugurated and kept by General Washington himself is still preserved, and the same kind of vegetation is still grown. When the investigation was undertaken in 1912 the box hedges and roses were doing poorly. The hedges were growing unsatisfactorily, and the roses were making a scant growth. There was danger of their complete failure.

From the laboratory examination made in 1912 it was first found that the garden soils contained the harmful salicylic aldehyde. The salicylic aldehyde probably formed in this soil from the decay of the high nitrogenous manure applied bountifully year after year. The decay of the large number of roots from the box hedges, which have grown in the soil since the days of Washington, may also have been a contributing factor.

As a remedy for the unsatisfactory soil conditions, a good system of underdrainage was installed. Lime was added to correct the acid condition of the soil, and a basic phosphate fertilizer was applied.

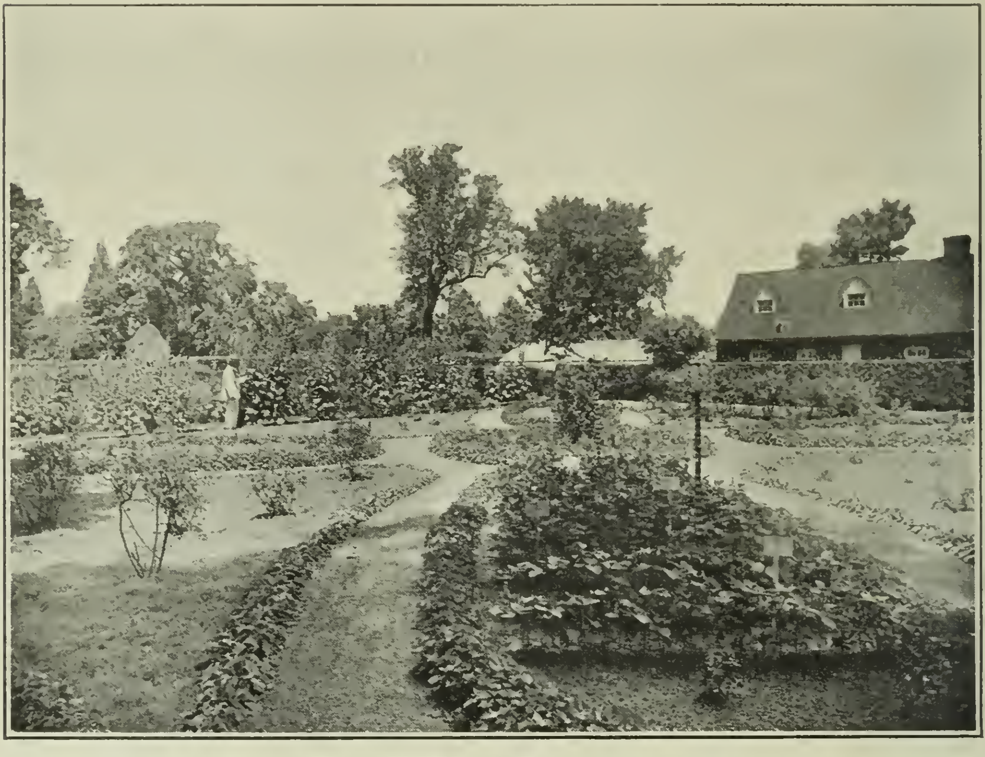
From the laboratory, greenhouse, and field results secured it has been found that the bad effects of salicylic aldehyde in soils were remedied by lime and acid phosphate, and that the aldehyde, when added to limed soils, was destroyed. As a result of this experiment the above treatments were suggested.

For several years following the treatment with lime and phosphate fertilizer the general condition of most of the garden was much improved, especially the box hedges. Roses in some parts of the garden, however, still made a very poor and unsatisfactory growth, while in other beds they did well. An examination of the poor rose bed in October, 1916, showed that the subsoil was stiff and gummy, while a nearby bed which grew good roses had a friable subsoil. A laboratory examination of the soil from the two beds showed them both to be alkaline, and both contained the same amount of soluble fertilizing salts. The poor soil at this time was found to contain aldehydes, while the good soil did not.

A greenhouse experiment made on the soil at this time also showed it to contain some soluble material of a harmful nature

(69). Cowpeas were grown in the soil in greenhouse bench beds. In one bed porous tubes containing carbon black were buried. The carbon black is a very good absorber, and removes any soluble organic substance from the soil moisture as it moves in and out the tubes. The cowpeas were much improved in the bed containing the carbon tubes. The untreated bed produced 412 grammes of green crop, and the bed containing the carbon 640 grammes, an appreciable increase in growth.

FIG. 69.



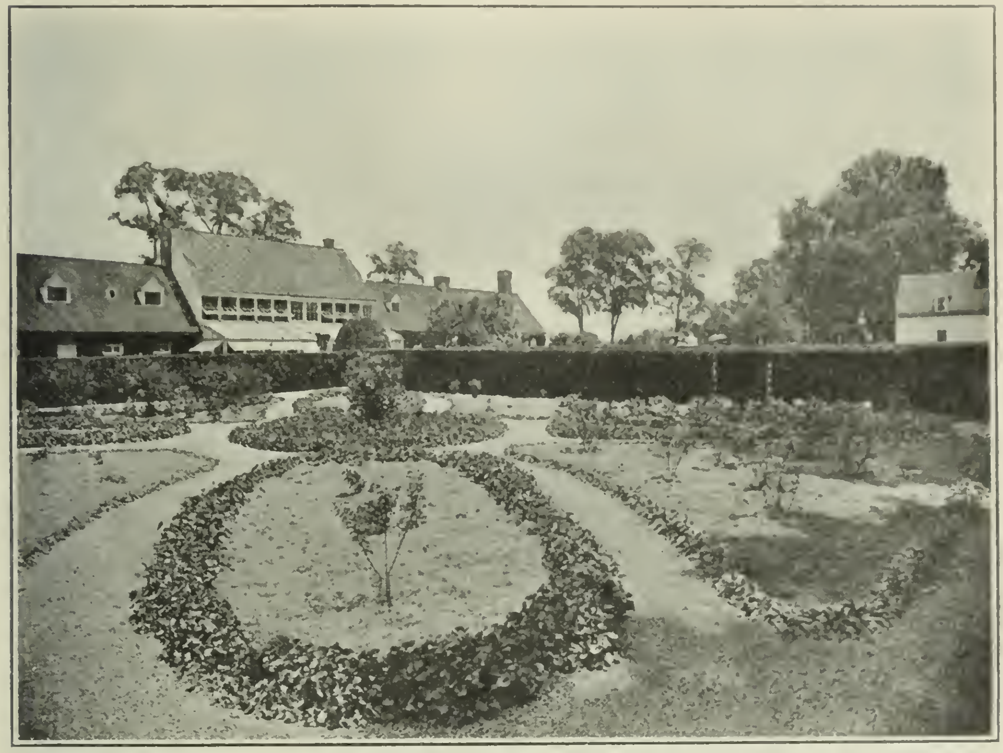
Showing the poor condition of the rose bushes in the Mount Vernon garden, a soil containing salicylic aldehyde, and the soil aldehyde experiment in the foreground.

It was three years ago that this soil was first found to contain aldehydes, and it is interesting to note that conditions were such that it could continue to be formed and remain in the soil over a period of years.

An experiment was planned and made in 1916 on the poor rose bed, which still contained aldehyde, in order to further study means of improving a soil which naturally contained aldehyde. The outline and results of the experiment are given below.

The bed was divided into four plots, each plot 4 feet by 6 feet. One bed was left untreated; to another lime was added at the rate of 1½ tons per acre; to the third acid phosphate was added at the rate of 800 pounds per acre, and to the fourth both lime and acid phosphate were applied. The lime and fertilizer were spaded and mixed in the soil to a depth of 6 inches and the soil allowed to stand for two weeks before seeding. In order to determine the effect of the treatments, cowpeas were grown as the test crop. Sixty-eight plants grew in each bed. They were planted May 26, 1916.

FIG. 70.



A view of the Mount Vernon garden on which the fertilizer aldehyde experiment was made. Note the unhealthy appearance of the rose bushes.

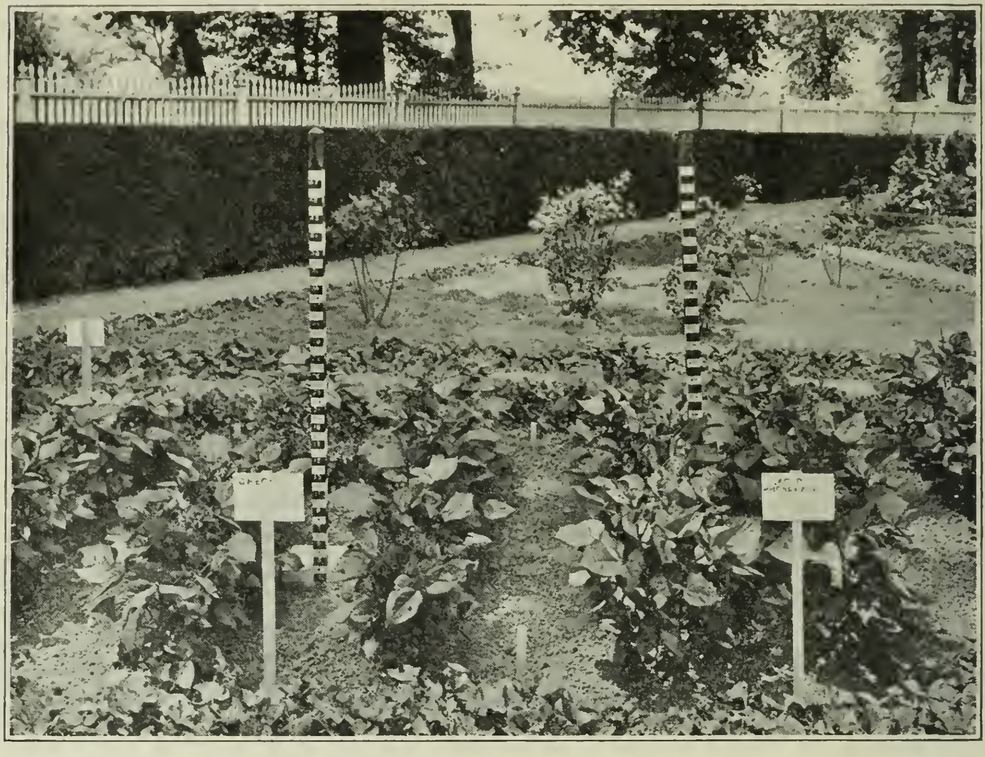
A laboratory examination of the soil from each plot, made several weeks after the fertilizers were applied, showed that the two plots to which lime was added were alkaline in reaction and the untreated and acid phosphate plots were neutral.

By July 1 the peas had made considerable growth. The plants on the differently treated plots were showing marked variation. At this time the growth on the untreated plot and that on the limed plot were about equal. The acid phosphate plot was much better—

approximately 20 per cent. better than the check. The plants were taller and the foliage more dense. The plot fertilized with both acid phosphate and lime was the best in the series; it was even better than the acid phosphate plot.

Photographs were taken at this time and are shown in Figs. 69, 70, and 71. Fig. 69 shows the flower garden in which the experiment was made, and a near view of the cowpeas growing in the soil experiment. Fig. 70 shows another section of the flower garden, with the soil experiment in the background near the box hedges. These two pictures show the arrangement of the rose beds encircled by a border of violets. The box hedge encloses the flower garden. The poor and straggling condition of the roses can be seen in each picture. A close view of the cowpeas is shown in Fig. 71. The comparative growths of the cowpeas on the check and acid phosphate plots are readily seen, and it is apparent that growth on the phosphate plot is much larger.

FIG. 71.



Effect of acid phosphate on cowpeas on a soil containing salicylic aldehyde.

The cowpeas were cut and the weight of vines taken on July 19. The results are given in Table XXIII.

TABLE XXIII.

Effect of Lime and Phosphate on Cowpeas in a Soil in Which Salicylic Aldehyde Formed and Remained for Several Years.

Treatment	Green weight per plot Grammes	Per cent. increase
Soil untreated	2600	—
Soil + lime	2750	2
Soil + acid phosphate	3770	40
Soil + acid phosphate + lime	4070	51

Lime alone did not seem to benefit this soil very much; there was an increase of only 2 per cent. in growth on the limed plot. The acid phosphate, however, produced 40 per cent. increase, and the acid phosphate and lime together 50 per cent. increase. As shown by this experiment and former work on this soil, conditions for growth are much improved by the addition of phosphate fertilizers and sufficient lime to prevent acidity. A thorough underdraining of the soil is essential. The improved drainage system installed permits of better aëration and consequently better oxidation. The heavy applications of stable and other organic manures which the soil received for years were discontinued. Fertilization with phosphates and lime, together with improved drainage, has rid the soil of harmful aldehydes, at least temporarily, and made it a better soil for crop growth. While it has been shown that the aldehydes no longer existed in the soil, it will be necessary to examine the soil from time to time to ascertain whether or not it will again be formed.

SUMMARY AND CONCLUSION.

The experimental results show that aldehydes are harmful to plant growth in aqueous culture solutions, in nutrient solutions, in soil in pots, and in soil in the field.

The effects of six aldehydes—namely, salicylic aldehyde, vanillin, benzaldehyde, heliotropine, formaldehyde, and paraformaldehyde—were studied in nutrient-culture solutions and each proved to be detrimental to plant growth.

The effect of the compounds varied according to the composition of the nutrient solutions. Salicylic aldehyde was least harmful in solutions composed of a high percentage of phosphates. Vanillin was least harmful in solutions with a high percentage of nitrates. Benzaldehyde was about equally harmful in all the nutrient solutions. It was slightly more harmful, however, in the high nitrate solutions than in the mainly phosphatic or potassic cultures. Paraformaldehyde was also least harmful in the phosphate culture, but formaldehyde and heliotropine showed harmful effects to an equal degree in almost all cultures, regardless of their composition.

Salicylic aldehyde and vanillin were found to occur in soils quite frequently, especially in soils of low productivity. The isolated substance from the soils was harmful to plants when dissolved in aqueous solution.

The two aldehydes were harmful in some soils and not in others. The field studies show that the added aldehydes disappeared in some soils and not in others. There was no harmful action where the aldehydes were destroyed. The soils in which the aldehydes were destroyed have strong biological activities, good oxidation powers, and are fertile.

The results of the experimental work presented in this paper further show that unfertile soils, where due to the presence of harmful aldehydes, can be made productive by good drainage and by the use of lime and certain fertilizers. This is demonstrated, *first,* by the growth of plants in nutrient solutions, where it is shown that phosphates partially overcome the bad effects of salicylic aldehyde, and that nitrates ameliorate the harmfulness of another aldehyde, vanillin. *Second,* by the more normal absorption of phosphates by plants growing in solutions containing salicylic aldehyde. *Third,* by the growth of plants in soil in pots, which shows that the harmful action of salicylic aldehyde is partially overcome by lime and phosphates and the effects of vanillin by lime and nitrate fertilizers. *Fourth,* by the growth of plants in field soils to which aldehydes were added, which again shows that lime and phosphates lessen the harmfulness of salicylic aldehyde and lime and nitrates alter the effects of vanillin. *Fifth,* by chemical tests in which it was shown that salicylic aldehyde, when added to a soil, was destroyed where lime and phosphates were added, and vanillin was destroyed where lime and nitrates were added. *Sixth,* by the improved productivity from the addition of lime and phosphates to a soil in which salicylic aldehyde was naturally formed and persisted for a period of years.

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Kelp. A. W. STOCKETT (U. S. Bureau of Mines).—For many years kelp has been recognized as a vaulable fertilizer, and has been used in this country and Alaska. Recently the Bureau of Soils has conducted an investigation of the extent and availability of giant kelp beds on the Pacific coast, and an appropriation of $175,000 was granted to the Department of Agriculture. A plant has been erected at Summerland, Cal., for demonstrating on a commercial scale the various processes of extracting potash and by-products from kelp. It has been estimated that there is on the Pacific coast, from Cape Flattery to San Diego, sufficient kelp to furnish 250,000 to 400,000 tons of K_2O per year. All of this, however, is not available, as in many places the kelp grows in exposed positions not readily accessible to machine cutters, and not within practical working distance of suitable harbors.

Several plants are now operating on the California coast, and the output from this source ranked second in 1917. The kelp is harvested by machine cutters on barges, and brought to shore, where it is either dried and ground, or reduced to a char, which may be used direct as a fertilizer material, or treated to produce a high-grade potassium chloride. The dried and ground kelp is a suitable material for use in mixed fertilizers containing not more than 6 per cent. of K_2O, but this source of supply can hardly be regarded as permanent under normal conditions. Figures of cost of production are not available, but from information received it seems that potash from kelp can not be produced at less than $2 per unit. The geographic situation of the kelp beds is unfortunate, as less than 1 per cent. of the fertilizer consumed is used west of the Rocky Mountains, and freight rates to eastern points would be prohibitive. The freight rate per unit of K_2O on the dried and ground kelp would amount to about $2, on the kelp char to about $1, and on the high-grade chloride to about 60 cents. No figures for freight rates via the Panama Canal are available. Attempts to transplant kelp from the Pacific to the Atlantic coast have so far been unsuccessful, as no suitable localities have been found, and the prospect of success of such a project is not considered promising.

Dust from Blast Furnaces. A. W. STOCKETT (U. S. Bureau of Mines).—The recovery of potash as a by-product in the manufacture of pig-iron was first investigated by R. G. Wysor, at the plant of the Bethlehem Steel Company. Dust settling in the stove and boiler passes was collected, and was found to contain nearly 10 per cent. of K_2O. Investigation showed that the potash recovered from this dust was only a small proportion of the total in the charge, being less than 2 per cent., and that 67 per cent. of the potash was lost in the primary washers and in the stack gases. Experiments with electrical precipitation proved that practically all of the dust could be precipitated successfully. A plant for collecting the dust is now being erected at a 400-ton furnace at the Bethlehem Steel Company's plant at Lebanon, Pa., and another plant is to be built in Alabama at an early date. Mr. Wysor states: "I venture to predict that in the future dry cleaning will be adopted in many blast-furnace plants, and that many thousands of tons of potash, hitherto wasted, will be reclaimed." Mr. Charles Catlett has said: "It is easy to remove the fumes and dust from the gases without interfering in any way with the operation of the furnace. The investment would be moderate, and the cost of operation of the potash-recovery plant low, while the gases would be improved for use in the stoves."

An investigation is being made to determine the total amount of K_2O lost in the dust of all the furnaces in the United States, but the figures are not yet available. Probably, however, the amount recoverable will exceed the total requirements of the country. Without taking into account the indirect advantage of cleaner gas for use in the stoves and gas engines, it may be safely stated that potash can be obtained from this source at a price that will enable it to compete successfully against the German potash under all conditions.

The iron industry, like the cement industry, is situated near the principal centres of demand for fertilizers, and should receive every inducement from the Government to erect plants for the recovery of potash, as it seems probable that these two industries could be made capable of permanently supplying the entire potash requirements of the country at a price that would encourage the more extended use of potash as a fertilizer, and thus increase the food supply.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

VARIANCE OF MEASURING INSTRUMENTS AND ITS RELATION TO ACCURACY AND SENSITIVITY.[1]

By Frederick J. Schlink, Associate Physicist.

[ABSTRACT.]

INSTRUMENTAL variance, which forms the major part of the discussion of this paper, is a factor whose effect in causing error in measuring instruments has hitherto been given but little consideration. In order to bring out the essential relations of variance characteristic, the paper opens with a discussion of accuracy and sensitivity, showing how each of these terms can be given precise definition with definite numerical significance. Such values when determined have important use in establishing the figure of merit or value of a given instrument or type of instrument. A distinction is drawn between the commercial accuracy commonly called for in direct reading instruments of the shop and plant, and the higher grade of accuracy required in the laboratory where commercial indications are normally subject to the application of corrections for error of calibration.

The error arising from whatever source, observed in an indication of the instrument, divided by the true value of the measured quantity, may be termed the *inaccuracy* at a given reading, the negative term being justifiable on the basis of custom and ease in application. The *accuracy* will be the reciprocal of the quantity just defined. The observed *error* of an instrument (or the correction) is utilized for adjusting observations before their use in calculation, while the *inaccuracy* and *accuracy* find their utilization in rating the quality or performance of the instrument.

An instrument is understood to be sensitive when it shows a change of reading for any change in the quantity being measured, a definition having little significance until means are available for expressing the sensitiveness numerically. Attention is called to the common inconsistencies in the sensitiveness rat-

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* Communicated by the Director.

[1] Scientific papers No. 328.

ings of familiar instruments and the suggestion is made that the unit of response, which is referred to the unit of change in the measured quantity in establishing the value of the sensitivity, should be based upon a definite and inherent characteristic of the instrument rather than upon an accidental factor such as the length of a pointer or an arbitrarily graduated scale. Thus in the case of an analytical balance, sensitivity should be referred, not to motion at the tip of the pointer but to the angular deflection of the beam (or pointer), so that comparison can be made of the true equilibrium properties of balances without reference to the accidental and unimportant factor of pointer length, which, within reasonable limits, is alterable at will. In a balance then the sensitivity would be determined as the angular deflection of the rest position of the beam per unit addition of load to the load pan, the first expressed in radians and the second in grams.

The necessity for distinguishing between insensitiveness and passiveness or sluggishness in an instrument is shown and consideration is given to the effect of friction in preventing response to certain small changes in the measured quantity, such that if the usual definition of sensitivity were accepted, we would find a phase of zero sensitivity followed by one of finite sensitivity, consequent upon the overcoming of the static friction which tends to prevent immediate response. Such a discontinuity in the value of sensitivity being irrational, in view of such a determination being dependent upon the absolute rather than the relative values of the quantities entering into the observation, we must modify our definition of sensitivity to this form: sensitivity in an instrument is the rate of change in the indication of such instrument with respect to change in the quantity being measured, it being necessarily assumed for the purposes of this definition that friction and lost motion in the mechanism have been eliminated or are negligible. The amount of the least alteration in the value of the measured quantity, producing instrumental response, divided by the initial value of the measured quantity may be called the *passivity* of the instrument at that point. Passiveness is a special case of the phenomenon of variance, next discussed.

Variance is defined as the range, at any given value of the measured quantity, or variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, after a steady reading has been attained,—the environment remaining unchanged.

The specific variance or *variancy* may be defined as the ratio of the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured,—divided by the measured quantity itself, the same assumptions applying as above as to the attainment of a steady state of indication and as to the maintenance of unchanged environment.

Determination of the variance is a most important part of the calibration of an instrument and appreciable error may arise from failure to recognize or express it. The paper illustrates the derivation of the variance from the hysteresis loop obtained when an instrument is subjected to a complete cycle of operation from a lower to a higher indication, and return,—while plotting point by point the instrumental readings (or corrections, or errors) against actual values of the quantity being measured. The importance of a study of this loop in analyzing instrument performance is shown, and figures are presented to exemplify the type and magnitude of the effect.

The sources of this hysteresis phenomenon are discussed, including the inelastic actions of certain force-equilibrating elements, and, at greater length, the purely mechanistic cause comprised in backlash. In illustrating this latter defect, the importance of maintaining constant or definite space relationships in the instrument linkwork is set forth, and detailed consideration is given to one of the most common causes of imperfect reversibility in instruments, that of the shifting zone of contact in a bearing whose journal fits in a slack or imperfectly constrained manner. The existence of mechanistic causes of irreversibility quite distinct from the ordinary concept of backlash is demonstrated, in the rolling of the pin or journal about the interior face of its slack bearing in a significant and fairly definite manner, capable of kinematic analysis and accounting satisfactorily for phenomena usually ascribed to the operation of frictional resistances simply. It is shown moreover that this cause produces an actual alteration and variation of the magnification or displacement ratio of the instrument from the point of reception to the point of registration of the quantity being measured.

The frequency curve method of delineation is applied to the expression of variance of an irregular nature, as found in instruments exhibiting bad workmanship or ill repair, and it is seen that the variance characteristic of such an instrument can be completely defined by reference to a family of frequency curves obtained in the following manner: One series of points will be plotted for readings taken at varying rates and amounts of increase of the measured quantity terminating in the value corresponding to the particular point of the scale under investigation, and another set for decreasing values terminating at the same point. Such a curve, in which frequency of occurrence of a particular reading or error is plotted against the true value of the measured quantity at that reading, gives the probability of occurrence of any amount of variation from, say, the mean instrumental reading.

Far from being a relatively unimportant source of inaccuracy in measuring instruments, it can be shown that the hysteresis or variance type of error demands consideration in practically every type of instrument, while in some (such as pointer-and-dial types of displacement-indicators) it is a preponderating factor in design and actually limits the application or utility of the instrument and sets the limit of sensitivity and accuracy practicably to be obtained.

Only brief consideration is given to the phenomenon of instrumental drift, which, having its source usually in elastic after-effects, requires special treatment from the point of view of the elastician.

A few means of reducing instrumental variance are given, including the use of special types of bearings in which slack or clearance can be reduced to a minimum without impairing easy operation; and the use of flexible elastic connectors between elements of the linkwork, instead of gears and racks or pin-and-link connectors. Such tape-like connectors which may wind on cam-shaped members to provide for correction of displacements to a linearly graduated scale, exhibit excellent properties in the matter of reversibility of calibration, and have important advantages over the more usual types of linkwork details.

The action of vibration in reducing instrumental variance is found to accord well with the principles previously set down, and it appears that, within limits, errors of result due to mechanical sources of variance can be considerably reduced by judiciously applied vibration treatment.

In designing and constructing an instrument, due consideration should be given to the effect of variance errors in practically limiting the sensitivity to be sought in adjustment, as well as the interval between the graduations and the smallness of the units of graduation. It is suggested that in view of this condition, the mean interval of graduation of laboratory instruments should not be less than five times the mean variance, while for commercial or plant instruments the ratio of mean scale interval to mean variance may be of the order of two to one. Likewise the sensitivity may easily be disadvantageously high, inducing erroneous estimates of the precision of results and requiring special care in the calibration and use of the instrument.

The factors of maximum or mean inaccuracy, (or accuracy) sensitivity, variancy and specific set (the amount by which the variance loop may fail of closure, divided by the range of the deflection cycle) may be referred to the total range of graduation instead of to particular values of the measured quantity under observation, as a convenient means of arriving at single significant numbers to be composed into a "figure of merit" for an instrument whose characteristics are being determined.

Persons having problems of instrument design on hand who may be desirous of obtaining copies of the full paper in advance of its publication, may do so by application to the author, at the cost of blue-print reproduction of the manuscript (34 pages and 7 figures).

MEASUREMENTS ON THE INDEX OF REFRACTION OF AIR FOR WAVE-LENGTHS FROM 2218A TO 9000A.[2]

By W. F. Meggers and C. G. Peters.

[ABSTRACT.]

A SURVEY of previous researches on refraction of air shows that many investigators have worked either with white light or with one monochromatic radiation, and dispersion measurements have been limited to a small interval of the spectrum. No index measurements exist for waves longer than those corresponding

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[2] Scientific papers, No. 327.

to orange light, and in the ultra-violet the dispersion formulæ disagree by more than 10 per cent. of the refractivity.

Recent work in spectroscopy makes it very desirable to have more accurate and extensive data on the index of refraction and dispersion of air. The international system of standard wave-lengths expresses the lengths of waves in air at 15° C and 760 mm., and all wave-length measurements made under other conditions require small corrections because of the effect of temperature and pressure of the air upon its optical dispersion. Furthermore, it is often desirable to multiply wave-lengths measured in air by the indices of refraction of air for these wave-lengths and thus convert them to their value in a vacuum. An accuracy of one part in several millions is now striven for in the measurement of wave-lengths and to maintain their relative accuracy in the reduction to vacuum values it is necessary to know the indices of refraction within a few units in the seventh decimal place.

For several years the Bureau of Standards has been engaged in the accurate measurement of wave-lengths. Interferometer comparisons of standard wave-lengths have been made throughout a large range of spectrum and the grating spectra of more than fifty of the chemical elements have been photographed and measured in the red and infra-red spectral regions. In connection with these accurate measurements of wave-lengths it was thought advisable to measure the absolute indices of refraction of air for the entire spectral region which is accessible to photography.

Accuracy and efficiency recommended the use of the Fabry and Perot interferometer for this work since this apparatus can be conveniently enclosed in a chamber in which the temperature and pressure of the air can be regulated as desired, and it also permits simultaneous observations for a large number of different wave-lengths. Sections of the circular fringes, produced by various radiations from a source of light illuminating the parallel plates of the interferometer, were photographed either with a grating or a rock salt prism spectrograph, first when the space between the plates was evacuated, and then when dry air at measured temperature and pressure was present.

The index of refraction for a particular wave-length was obtained directly from measurements of the photographed interference fringes which allowed the ratio of lengths of this wave in vacuum and in air to be calculated. Observations were made at spectrum intervals of about 40 A from the extreme ultra-violet at 2200 A, through the visible spectrum and in the infra-red to 9000 A.

Complete sets of observations were made on dry air at atmospheric pressure and at temperatures of 0°C, 15° C and 30° C.

These are quite closely represented by the following dispersion formulæ of the Cauchy form.

$$(n-1)_0 \times 10^7 = 2875.66 + \frac{13.412}{\lambda^2 \times 10^{-8}} + \frac{.3777}{\lambda^4 \times 10^{-16}}$$

$$(n-1)_{15} \times 10^7 = 2726.43 + \frac{12.288}{\lambda^2 \times 10^{-8}} + \frac{.3555}{\lambda^4 \times 10^{-16}}$$

$$(n-1)_{30} \times 10^7 = 2589.72 + \frac{12.259}{\lambda^2 \times 10^{-8}} + \frac{.2576}{\lambda^4 \times 10^{-16}}$$

These observations are used in the construction of a table giving the corrections which must be applied to wave-lengths measured in air where density is not normal. A table of corrections to convert wave-lengths or frequencies measured in air to their values in a vacuum is also given.

The coefficient of index variation with temperature was found from these measurements to be a function of the wave-length. For long waves this optical temperature coefficient is identical with the density temperature coefficient, *i.e.*, $\frac{1}{273}$ but as the ultra-violet absorption band is approached it increased rapidly, becoming $\frac{1}{258}$ at 2500 A.

There seems to be no definite evidence of any strong absorption of infra-red light by dry air and it is therefore possible to represent the optical dispersion of air by the first term of Sellmeier's formula quite satisfactorily.

THE INFLUENCE OF QUALITY OF GAS AND OTHER FACTORS UPON THE EFFICIENCY OF GAS-MANTLE LAMPS.[3]

By R. S. McBride, W. A. Dunkley, E. C. Crittenden, and A. H. Taylor.

[ABSTRACT.]

THIS paper describes the apparatus and methods employed and the results obtained in studying the effects of several variables such as gas pressure, gas adjustment, air adjustment, and gas

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[3] Technologic papers, No. 110.

quality upon the performance of various types of gas mantle lamps. Several tables and curves are given to assist in the presentation of the results.

The experiments show that if the pressure of gas supplied to a mantle lamp is increased above the minimum pressure at which the lamp will operate, other conditions remaining the same, a regular increase in gas consumption is observed. The candlepower and efficiency of the lamp also increase until maxima are reached, the efficiency attaining its maximum first. Further pressure increases results in decreases in the efficiency and candlepower. Within the pressure range tested (1½ to 8 inches of water) it was found that pressures of from 2 to 4 inches gave the highest efficiencies regardless of the pressure at which the lamp was adjusted to give maximum candlepower.

The effect of gas adjustment changes was found to be similar to the effect of pressure changes. It was found that if a lamp which had been adjusted to give maximum candlepower at a given pressure, was readjusted so as to use slightly less gas, the efficiency usually increased somewhat. It was also found that the adjustment devices on various lamps had markedly greater effects on lamp performance in certain portions of their ranges than in other portions.

The effects of air-shutter adjustment depended upon the quantity of gas being used. In general the gases of higher heating value required the lamp to have greater air shutter opening to give maximum efficiency than did the gases of lower quality.

It was found that if a lamp was given the most favorable adjustment when burning each given quality of gas, there was little difference between the various efficiencies obtained. In comparing city gas (mixed coal and water gases) of about 650 Btu with water gas of about 540 to 575 Btu it was found that the latter gave slightly higher efficiencies in upright type of lamps. In the comparison of coal gas and water gas, each of about 540 Btu it was found that in nearly all cases there was slight advantage in efficiency for the water gas. City gas enriched with benzol from about 650 to 740 Btu gave somewhat higher efficiencies in upright lamps than did the unenriched gas. Natural gas burned in lamps designed for it gave efficiencies about 20 per cent. lower than did manufactured city gas burned in artificial-gas lamps of similar type. The conditions did not, however, permit of as great exactness in this determination as in those previously mentioned.

Selecting the maximum candlepower and efficiency points in several tests with various cases and studying these values in connection with the rates of heat input at which they were obtained, it was found these maximum points were distributed over a very wide range of heat inputs. It was found that in general these maximum values were not determined by rates of heat input at which they occurred. On the other hand, a maximum candlepower obtained in a given test was likely to be higher if it was accompanied by a high rate of heat input. It was found that it was practically impossible to control all the conditions affecting a mantle lamp with sufficient exactness to ascertain a most efficient rate of heat input.

METRIC MANUAL FOR SOLDIERS.[4]

The aim of the metric manual is to give to the American soldiers the grasp of the metric system which will enable them to think and work in metric units.

As recommended no tables of equivalents need be memorized. Brief tables and a vocabulary are given for reference. The units are described by actual examples likely to be encountered in military work.

Heavy Mallet Locomotive for Norfolk & Western Railway. Anon. (*Engineering News-Record,* vol. 81, No. 20, p. 898, November 14, 1918.)—A Mallet locomotive with a weight of 535,000 lbs. without tender or 747,000 lbs. with tender has been built for the Norfolk & Western Railway. There are eight drivers on a side, with a total driving wheel base of 57 ft., 4 in. The weight on the drivers is 472,000 lbs. The weights on the leading truck and trailing truck are respectively 28,000 and 35,000 lbs. The total wheel base is 92 ft., 11¼ in. The tender, which weighs 212,000 lbs., has a water capacity of 12,000 gallons and a coal capacity of 20 tons.

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[4] Miscellaneous Publications, No. 21.

Freeing the Range Country and Forest Reserves of Predatory Animals. (*U. S. Department of Agriculture*).—Skilled hunters in the employ of the Government are waging persistent warfare against the predatory animals that prey on sheep and cattle in the Western States. Their efforts are encouraging stockmen to increase livestock production on the Federal forest reserves as well as in the range country, and they are protecting the sources of war supplies of meat, leather and wool now in the Western grazing districts.

Hunters of the Biological Survey of the United States Department of Agriculture have killed 70,713 predatory animals during the last three years, which has resulted in a direct saving estimated at nearly $5,500,000 a year to the stockmen of the Rocky Mountain section. The total kill since the fall of 1915, when the work was started, includes 60,473 coyotes, 8094 bobcats, 1829 wolves, 201 mountain lions and 137 bears. The Government experts estimate that the annual depredations among cattle and sheep effected by single predatory animals are as follows: Wolf, $1000; stock-killing grizzly bear, $500; mountain lion, $500; bobcat, $50, and coyote, $50.

Stockmen in sections where the predatory animals are obnoxious are aided by the Government in ridding the ranges of them. In some localities the stockmen's associations coöperate with the State and Federal authorities in the extermination campaign, professional hunters being employed to detect and kill the prowling animals that prey on sheep and cattle. Illustrative of the scope of this work, the total income from pelts of predatory animals killed by Government nimrods last year amounted to approximately $100,000. In addition, many other animals, whose skins could not be reclaimed, were killed by poisoning. Ordinarily the United States Biological Survey has from 250 to 350 professional hunters permanently in its employ. The area wherein predatory animal control is practiced includes ten districts: Montana, Idaho, Washington and Oregon, Nevada and California, Utah, Wyoming and South Dakota, Colorado, Arizona, New Mexico, and Texas.

During the last twelve months 26,226 coyotes, 3458 bobcats, 849 wolves, 85 mountain lions, and 41 stock-killing bears have been disposed of, at an annual saving of approximately $2,400,000 in domestic stock.

Recently a Government hunter shot two male wolves which had killed 150 sheep and 7 colts on two Wyoming ranches, while another trapper bagged a pair of old wolves which had a record of killing $4000 worth of live stock a year. A third trapper destroyed 85 coyotes and 2 bobcats in one month, using 6 horses and 200 traps over a trap line varying from 50 to 100 miles in length. A coyote was recently captured which had destroyed $75 worth of sheep in one week. Two wolves, seven mountain lions, and a huge grizzly bear, the largest of its species ever killed in the Yellowstone Park section, are the kill of another Government sharpshooter. These results are typical of the campaign destined to free the Rocky Mountain range country of predatory animals.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

RATE OF PUPILLARY DILATATION AND CONTRACTION.[1]

By Prentice Reeves.

[ABSTRACT.]

AN examination of the literature showed very little available material on the operation of the normal pupil. In the first part of this experiment instantaneous flashlight photographs were taken of the pupils of two subjects for eight brightness levels, including total darkness at one end and the just tolerable reflection of full sunlight from white paper at the other end. The effect of exposing one or both eyes to the sensitizing field was determined for both subjects throughout the brightness range.

From these curves six brightness levels were chosen and the pupils of six subjects were measured, one of the first subjects being used in this series to check the method. In this part of the experiment a motion picture camera was used and a lamp bank displaced the flashpowder.

The rate of closing of the pupil was measured by taking motion pictures of an eye fully adapted to darkness, hence maximum diameter, as it closed to a diameter almost its minimum. The same six subjects served, as well as two others, and the average pupil closed in less than five seconds. The greater part of the contraction occurs within the first two seconds.

The rate of opening was determined for seven subjects, the above six and one other, as the pupil opened from near a minimum to a maximum diameter. The average pupil required from three to ten minutes to reach its maximum diameter.

The curves plotted of these results are similar in shape, though marked individual differences are shown as well as variations in the results from the same subject on different days.

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* Communicated by the Director .

[1] Communication No. 66 from the Research Laboratory of the Eastman Kodak Company, published in *Psychological Review* 25, 1918, p. 330.

Dust from Cement Works. A. W. STOCKETT (U. S. Bureau of Mines).—The first cement plant to recover potash from the kiln dust was that of the Riverside Portland Cement Company, in California. Owing to litigation with near-by fruit growers who claimed that the fine dust escaping from the kilns was causing damage to the fruit trees, the company was compelled to install an electrical dust-precipitating plant to abate the alleged nuisance. Analysis of the dust thus collected showed that it contained about 10 per cent. K_2O. The dust collector was completed early in 1913 and has been continuously and successfully in use ever since. What was originally considered an additional expense in the manufacture of cement has proved to be a highly profitable by-product.

Another plant is successfully using the same method at Security, Md., and both electrical precipitation and other methods of collecting dust are being used at different plants. A point in favor of dust collection is that no change in present methods of manufacturing cement is involved, and at one plant the installation has led to a reduction of 10 per cent. in fuel consumption, owing to the more careful attention required in burning the cement.

An investigation recently completed by the Bureau of Soils indicated that the probable maximum amount of potash that might be recovered from all the cement works in the country would be 100,000 tons of K_2O per year. It is not likely that dust-collecting plants will ever be installed at all cement works, but it seems reasonable to expect that the amount of K_2O to be derived from this source should reach 50,000 tons a year, or 20 per cent. of the total normal requirements. Probably this amount could be increased somewhat by using, where available, rock containing more K_2O in the raw mix.

An objection raised to cement-kiln dust as a source of potash in manufacturing fertilizers is that if used in large quantities the lime content will cause reversion of the soluble phosphoric acid in the phosphate and loss of the ammonia in ammonium sulphate. The K_2O content of cement-kiln dust is also too low to permit its use as the only source of potash in a fertilizer that is to contain more than 3 per cent. of K_2O. However, these objections can easily be overcome, and some potassium sulphate containing 40 per cent. of K_2O is now being marketed by one of the cement works.

Published figures on the cost of production show that, allowing for the amortization and interest on investment, potash can be produced by the cement companies at 30 to 50 cents a unit of K_2O, which will enable them to compete successfully with the German salts even at pre-war prices.

Thus the cement industry, especially in view of its geographical situation, seems one of the most promising sources of a permanent American supply of potash, and the Government should offer every possible encouragement to install plants for the recovery of potash, especially in cement works east of the Mississippi, as more than 90 per cent of the commercial fertilizer used in the United States is consumed in that area.

NOTES FROM THE HESS-IVES LABORATORIES.*

A NEW PHOTOGRAPHIC MORDANT DYE PROCESS.

By Frederic E. Ives.

The first photographic mordant dye process to attract attention was the silver-iodide process of Dr. Traube (U. S. Pat. 1,093,503, 1914). Metallic silver photographic images converted to silver iodide and immersed in solutions of basic dyes become strongly colored. If the dye is then fixed by tannin, the silver-iodide can be dissolved out, leaving a transparent dye image. Traube's method was improved upon by Tauleigne and Mazo (U. S. Pat. 1,059,917, 1913), who showed how to produce a silver-iodide image having a stronger affinity for the basic dyes, and incidentally that by first hardening the gelatine with alum and then treating the silver-iodide image with a strong solution of potassium iodide it was made so transparent that for most purposes it was unnecessary to dissolve out the silver-iodide image. The step of hardening the gelatine in alum to prevent it from softening and dissolving in the strong potassium iodide solution was omitted in the United States patent specifications, but was published in the *British Journal Photographic Almanac,* 1912, page 653. Hoyt Miller (U. S. Pat. 1,214,940, 1917), as a result of experiments with the process without alum hardening, declared the process unworkable, and broadly claimed the production and dyeing of a transparent silver-iodide image, he hardening the gelatine with formalin. I have myself operated the Tauleigne-Mazo process with perfect success.

Incidentally it had been discovered that silver ferrocyanide, silver chromate and some other silver salts could be similarly dyed, but not with satisfactory results. Fox (U. S. Pat. 1,166,123, 1916), disclosed the fact that a vanadium-toned silver image mordanted basic dyes, and Crabtree and Ives (priority to Crabtree) independently discovered that a copper-toned image had the same property to a very notable and useful degree. The copper-toned image, like the transparent kind of silver-iodide image, is sufficiently transparent for most purposes without " fixing out," but can be made perfectly transparent by fixing "hypo" without first fixing the dye image with tannin. It has the disadvantage for some purposes that the copper-ferrocyanide image is itself colored (red-brown) and will not serve as the base for pure blue and green images. It has proved perfectly satisfactory for the production of orange-red images in combination with a cyanotype print in the same colloid layer in my colored moving picture process (U. S. Pat. 1,278,668, 1918).

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* Communicated by the Laboratories.

Recently, I have discovered a new method of producing mordant-dye photographic images, which I think is superior to any heretofore known. The mordant is a chromium compound the exact nature of which I have not yet determined, but it is not silver chromate, which is of a deep red color, while the image which I produce previous to dyeing is of a very pure, though pale, yellow color. It is produced very simply, quickly and cheaply, by bleaching the silver image in a solution of equal parts of potassium ferricyanide and chromic acid, the action of which is analogous to that of potassium iodide in that if the solution is weak the image is not transparent, but if the solution is strong, the image is perfectly transparent and of a pale, though pure yellow, color. It is necessary to wash out the free chromic acid after bleaching. The pale yellow image thus produced has a much stronger affinity for some of the basic dyes than either silver iodide or copper ferrocyanide. In fact, the silver image, for the best results, must be thin and superficial.

My bleaching solution is made with one ounce each of potassium ferricyanide and chromic acid in one gallon of water, at which strength it acts very quickly and produces a transparent yellow image. Transfer to running water should be made immediately when the image is completely bleached, to avoid over-hardening of the gelatine by the chromic acid. Long washing is necessary to clear out the free chromic acid, but it discharges rapidly in water containing a little soda bicarbonate, and the image also dyes up quicker and clears more rapidly after dyeing if the soda bicarbonate is used. I always use it, but too long immersion whitens the image, reduces its transparency and produces a weaker, though still strong and brilliant dye image.

A typical dye bath is made by dissolving 10 grains of saffranin in 4 ounces of alcohol and adding it to one quart of water made slightly acid with acetic acid. For complete dyeing, an immersion of half an hour or more may be necessary. This will stain the entire film deeply, after which it may be cleared by washing in water containing a very little acetic acid. Other very active dyes are malachite green and auramine.

The images which have been whitened by long soaking in soda bicarbonate solution have the same appearance and transparency as silver ferrocyanide images, but have many times more mordanting power—more even than silver iodide.

The Sign of Potentials. O. P. WATTS. (*Proceedings of the American Electrochemical Society*, September 30–October 2, 1918.)—A phenomenon which attracted much attention from the early electrochemists was the displacement of metals from solution by other metals. The relative displacing power of many of the elements was thus measured, and they were arranged in the order of their power of precipitating other metals; this constituted the electrochemical series. Electrochemists, however, have not been satisfied with mere order, but have measured and expressed in volts the distances between different metals, so that the old electrochemical series has been converted into the modern table of potentials. In spite of their inaccuracy and the very limited number of electrolytes in which the potentials of metallic conductors are as yet known, these tables have proved of the greatest value in explaining the phenomena encountered in electrolysis, and in successfully predicting what will happen when certain electrodes are employed in a particular electrolyte.

According to these tables, magnesium, zinc, etc., are electropositive metals, while platinum and gold are highly negative. If a voltaic cell be formed by using two of the above metals as electrodes in a chlorine solution, the flow of current through the electrolyte will be from the metal of higher potential to that of lower potential, and the E.M.F. of the cell will be equal to the difference of potential between the metals.

For many years this convention regarding the use of signs was unanimous, and writers on electrochemical subjects either gave such a table or referred to zinc, etc., as electro-positive. In works on the corrosion of iron, dating from 1822 to 1918, wherever stimulation of rusting by local action was mentioned, the iron was said to be positive to the copper, graphite, or whatever constituted the other electrode of the cell. Similarly, the protective action of zinc was ascribed to its being electro-positive to iron.

In the gravity cell, we consider what is called an electric current as passing from the positive zinc plate through the electrolyte to the negative copper; and because electricity flows only in closed circuits it must return to the zinc through the wires, etc., which constitute the remainder of the circuit. The terminal of an ammeter, voltmeter, or other D. C. electrical instrument by which the current should enter is marked by a plus sign, and, therefore, must be connected to the copper plate to receive the current that passes through the electrolyte to this electrode. The futility of attempting to represent completely the electrical conditions in a voltaic circuit by attaching a single sign to either electrode was recognized by the early electrochemists when they spoke of the zinc as "the positive plate" (we should now say electrode), "but the negative pole of the cell." There is yet to be found a simpler way of designating the relation of the zinc electrode to the whole electrical circuit; for the current will flow from the zinc into the electrolyte, provided that it is permitted to return to the zinc again from that portion of the circuit which lies outside of the cell; yet the driving force resides within the cell.

Faraday gave us the terms anode (up or entering way) and cathode (down or leaving way), and we designate the anode of the electrolytic cell, from which the current enters the solution, by a plus sign, and the cathode, by which it leaves, by the minus sign. The use of signs is the same in the electrolyte as in the voltaic cell—a simple and easily understood arrangement. The table of potentials consists, in accordance with the ionic theory, of the "potential of the solution minus the potentials of the metals." The table as rewritten by those who contend for a change of sign consists of "the potentials of the metals minus the potential of the solution." Since ions of the metals are usually considered to be charged positively, when a strip of zinc, for example, is thrust into an electrolyte, zinc ions go into solution carrying positive charges, therefore lowering the potential of the zinc and raising that of the solution, so that the zinc should be negative to the solution. It would thus appear that the advocates of the minus sign for the potential of zinc are contending for the truth, as opposed to error; but the physicists who have been the most ardent advocates of this change of sign tell us that the whole matter of sign is wrong in electricity; that what we call a positively charged ion has less than the normal number of electrons, and that our negatively charged ions have an excess of electrons, and that the "flow of the electric current is really in the opposite direction to that which is now accepted."

It follows that if the proposed change of sign in potentials be adopted, carrying with it all the confusion which will result in electrochemical literature and the inconsistencies which have been pointed out, we shall still fail to express the truth regarding the potentials of metals, for the latest theory of the nature of electricity leads us to believe that the zinc electrode is really at a higher potential than the electrolyte, and, consequently, the plus, and not the minus, sign correctly indicates the potential. It, therefore, seems for the best interests of electrochemistry that until such time as the scientific world is ready to revise the entire terminology of the electric circuit, the time-honored custom in regard to writing the electrochemical series and tables of potentials should be followed.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting Held Wednesday. November 20, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 20, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 15.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The chairman then introduced Dr. Alfred B. Hitchins, Director of the Ansco Company's Research Laboratory, Binghamton, N. Y., who presented a paper entitled "Modern Applications of Photography." The speaker outlined the present position of photography in science, industry and research work, and discussed its specific applications to spectroscopy, photomicrography, x-rays, bacteriology, medicine, and aerial photography. He described briefly the work of the Ansco Laboratory and its staff and some of the problems under investigation. The subject was illustrated by lantern slides.

A discussion followed the paper, in which Messrs. Levy, Jennings, Koch, the chairman, and others participated.

After a vote of thanks to the speaker the meeting adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard University
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K., Lieut. Com.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., 1st Lieut.	Air Service, U .S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade

Name and rank	Branch of service	Location
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Washington
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington

Name and rank	Branch of service	Location
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Casper W., Major	Medical Corps, Division of Food and Nutrition	Washington
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Pemberton, Henry R.	U. S. Naval Air Service	Key West, Fla.
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase. Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Railway Artillery Reserves	France
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York

Name	Appointment	Location
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Wahington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma

Name	Appointment	Location
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Rittmann, Walter F.	Consulting Chemical Engineer, U. S. Bureau of Mines	Pittsburgh
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting Held Wednesday, November 6, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 6, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2723.—The Prestwich Fluid Gauge.

The following reports were presented for final action:

No. 2722.—The Calorizing Process, Diamond Power Specialty Company, Detroit, Mich.; recommended that the Edward Longstreth Medal be awarded to Tycho Van Allar, of Schenectady, N. Y., and the Certificate of Merit to Emery G. Gilson, of Schenectady, N. Y.

No. 2724.—The Rolin Adjustable Grate, Charles W. Rolin, of Philadelphia, Pa.; recommended that the Certificate of Merit be awarded to Charles W. Rolin, of Philadelphia, Pa.

GEO. A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, November 13, 1918.)

RESIDENT.

DR. THOMAS D. DELBRIDGE, Chief Chemist, Atlantic Refining Company, 3144 Passyunk Avenue, Philadelphia, Pa.

MR. HUTTON KENNEDY, Manufacturer, Gaul and Adams Streets, Philadelphia, Pa.

NON-RESIDENT.

PROFESSOR B. M. BRIGMAN, Engineering Department, University of Louisville, 119 West Broadway, Louisville, Ky.

LIEUTENANT J. D. JAQUES, C. E. C., U. S. N. R .F., Building 107, Navy Yard, Boston, Mass.

MR. HENRY HOBART KNOX, Mining Engineer, 68 East Eighty-sixth Street, New York, N. Y.

MR. ROLF KNUDSEN, Electro-chemical Engineer, 32 Vandeventer Avenue, Princeton, N. J.

MR. DAVID PELTON MOORE, Patent Attorney, Real Estate Trust Building, Washington, D. C.

LIFE.

MR. CHARLES H. COLVIN, Mechanical Engineer, 61 Poplar Street, Brooklyn, N. Y.

CHANGES OF ADDRESS.

MR. FRANK M. ASHMEAD, 816 Ivy Street, Pittsburgh, Pa.

MR. JOHN CALDER, 35 West Thirty-ninth Street, New York, N. Y.

MR. G. E. CHAMBERLAIN, 1650 East William Street, Decatur, Ill.

CAPTAIN THEOBALD F. CLARK, in care of Mrs. Charles Nevin, 2021 Locust Street, Philadelphia, Pa.

MR. C. R. COLLINS, 805 Lowman Building, Seattle, Wash.

MR. R. BURDETTE DALE, 1111 Brown's Avenue, Erie, Pa.

MR. FRED DENIG, 211 Whedbee Street, Fort Collins, Colo.

MR. BYRON E. ELDRED, 18 East Forty-first Street, New York, N. Y.

MR. E. L. GIBBS, 402 Barrs Street, Jacksonville, Fla.

LIEUTENANT A. H. GFRORER, 19 Race Street, Hillside, Elizabeth, N. J.

MR. WILLIAM HOPPIN, 808 Second Avenue, Detroit, Mich.

MR. A. ATWATER KENT, Ardmore, Pa.

MR. J. GEORGE KLEMM, JR., Haverford, Pa.

MR. CLINTON N. LAIRD, 106 Tenth Street, Garden City, Long Island, N. Y.

LIEUTENANT COMMANDER CHARLES LONGSTRETH, U. S. N. R. F., New Castle, Del.

MR. NORMAN MACBETH, 227 West Seventeenth Street, New York, N. Y.

MR. T. E. MITTEN, 1520 Spruce Street, Philadelphia, Pa.

DR. ANNABELLA E. RICHARDS, 2503 Maryland Avenue, Baltimore, Md.

MR. W. H. SHARP, The Wellington, Nineteenth and Walnut Streets, Philadelphia, Pa.

MR. FRANCIS R. WADLEIGH, Room 117, New Interior Building, War Industries Board, Washington, D. C.
MR. J. D. WILLIAMSON, JR., Ogontz, Montgomery County, Pa.
MR. E. H. UTLEY, Vice President, Bessemer and Lake Erie Railroad Company, 727 Union Arcade, Pittsburgh, Pa.

NECROLOGY.

Mr. F. S. Allen, 48 Fairfield Avenue, Hartford, Conn.
Mr. Richard Biddle, Wanderer's Rest, Sewanee, Tenn.
Mr. William Burnham, Morris Building, Philadelphia, Pa.
Dr. E. W. Caldwell, 480 Park Avenue, New York, N. Y.
Mr. James Douglas, 99 John Street, New York, N. Y.
Mr. William L. DuBois, 415 Chestnut Street, Philadelphia, Pa.
Mr. Robert C. Lippincott, 537-39 Land Title Building, Philadelphia, Pa.
Mr. W. J. McCahan, Front and Chestnut Streets, Philadelphia, Pa.
Mr. Marshall Miller, 911 North Eighth Street, Philadelphia, Pa.
Dr. Isaac Norris, Bryn Mawr, Pa.
Mr. F. C. Robinson, 3144 Passyunk Avenue, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

ABRAHAM, HERBERT.—Asphalts and Allied Substances. 1918.
American Electrochemical Society.—Transactions, vol. xxxii. 1917.
BUCHER, E. E.—Vacuum Tubes in Wireless Communication. 1918.
CAMPBELL, ANDREW.—Petroleum Refining. 1918.
FERRY, E. S.; SHOOK, G. A., and COLLINS, J. R.—Practical Pyrometry, 1917.
GILLETTE, H. P., and DANA, R. T.—Handbook of Mechanical and Electrical Cost Data. 1918.
LEUPP, F. E.—George Westinghouse; His Life and Achievements. 1918.
MACELWEE, R. S.—Ports and Terminal Facilities. 1918.
OSBORNE, T. B.—The Vegetable Proteins. 1918.
WHITHAM, J. M.—Water Rights Determination from an Engineering Standpoint. 1918.
WOOD, H. C.; REMINGTON, J. P., and Others.—Dispensatory of United States. Edition 20. 1918.
YOUNG, SIDNEY.—Stoichiometry. 1918.

BOOK NOTICES.

AIRPLANE CHARACTERISTICS: A SYSTEMATIC INTRODUCTION FOR FLYER AND STUDENT AND ALL WHO ARE INTERESTED IN AVIATION. By Frederick Bedell, Ph.D. Ithaca, N. Y., Taylor & Company, 1918, 123 pages, one plate and forty-three illustrations in the text, no index. 8vo. Price, $1.60 net.

This manual is devoted entirely to the mathematical and physical problems of flight in connection with heavier-than-air machines, for which the author uses "airplane" in preference to the more familiar "aeroplane," a substitution which it is to be hoped will be generally followed. He defines airplanes as flying machines which are "heavier than air, have wing surfaces for support in the air, with stabilizing surfaces, rudders for steering and power-plant for propulsion." Two types are distinguished: "Tractor," in which the propellers are in front of the engine, and "Pusher," in which the propeller is behind it.

The book is liberally illustrated with line drawings showing the principles of stability, equilibrium and other data connected with the art of aviation. An interesting addition to terminology is the expression "parasite resistance," by which is meant all resistance that does not contribute to the lift. A glossary of terms is given in which we note several new words, such as "burble-point" and "yaw," and new uses of familiar words, such as "bank," used as a verb, meaning to incline a plane laterally. The term "dope," of course, appears, but this is now quite familiar in its aviation sense.

The book is stated to be incomplete, a considerable amount of material intended to be included in it not being ready for publication. This will appear, it is hoped, early in 1919. The work will be interesting and useful to the student of the theory of heavier-than-air-machines..

HENRY LEFFMANN.

CENSUS OF DYES AND COAL-TAR CHEMICALS, 1917. Tariff Information Series No. 6, United States Tariff Commission. Washington, Government Printing Office. 1918. 73 pages, 8vo.

This is a very interesting and valuable account of the conditions of coal-tar industries in this country from 1909 to the end of 1917. Space does not permit of an extended summary of the data presented, but some of the facts must be mentioned. Before the opening of the European war but little manufacture of coal-tar products was carried on in this country. A few colors were made, but mostly from the so-called intermediates. Now nearly two hundred firms are engaged in the several lines depending on the utilization of tar. The story of the indigo industry is interesting. It is generally known that for some years before the war the bulk of indigo used in the world at large was made in Germany by synthesis. In 1909 the United States imported over eight million pounds of indigo, of which all but three hundred thousand pounds came from Germany. The price was less than twenty cents per pound. Since the beginning of 1916 no indigo has come from Germany. In that year about three and a half million pounds came from China and over a million from England. The cost was over one dollar per pound. Any one interested in the economic questions growing out of these industries will find the pamphlet of great use. HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Electro-Analysis, by Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. Sixth edition, revised and enlarged, 344 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $2.50.

Technical Books of 1917: Compiled by the Applied Science Reference Department, Pratt Institute, Free Library, Brooklyn, New York. 28 pages, 16mo. Brooklyn, Institute, 1918.

U. S. Bureau of Mines: Efficiency in the Use of Fuel Oil; a handbook for boiler-plant and locomotive engineers, by J. M. Wadsworth; 86 pages, illustrations, plates, 16mo. Monthly Statement of Coal-mine Fatalities in the United States, June and July, 1918; compiled by Albert H. Fay; 2 pamphlets, 8vo. Technical paper 139, Low-rate Combustion in Fuel Beds of Hand-fired Furnaces, by Henry Kreisinger, C. E. Augustine and S. H. Katz; 54 pages, illustrations, 8vo. Technical paper 154, Suggestions for Improved Methods of Mining Coal on Indian Lands in Oklahoma, by J. J. Rutledge and Daniel Harrington; 36 pages, illustrations, plates, 8vo. Technical paper 186, Methods for Routine Work in the Explosives Physical Laboratory of the Bureau of Mines, by S. P. Howell and J. E. Tiffany; 63 pages, 8vo. Technical paper 192. Production of Explosives in the United States during the Calendar Year 1917, with notes on coal-mine accidents due to explosives and list of permissible explosives tested prior to April 30, 1918; compiled by Albert H. Fay; 21 pages, 8vo. Technical paper 197, Use of the Hydrogen-Volatile Matter Ratio in Obtaining the Net Heating Value of American Coals, by A. C. Fieldner and W. A. Selvig; 13 pages, illustrations, 8vo. Technical paper 204, Economic Operation of Steam Turbo-electric Stations, by C. J. Hirshfeld and C. L. Karr; 29 pages, illustrations, 8vo. Technical paper 206, Coke-oven Accidents in the United States During the Calendar Year 1917; compiled by Albert H. Fay, 19 pages, 8vo. Technical paper 208, How to Improve the Hot-air Furnace, by Charles Whiting Baker; 20 pages, 8vo. Washington, Government Printing Office, 1918.

Production of Crude Oil: Letter from the Director of the Bureau of Mines transmitting, in response to a Senate resolution of September 11, 1916, certain information in regard to the production and consumption of crude petroleum and other mineral oils as far as statistics are available; also a letter in response to a Senate resolution of September 13, 1918, transmitting certain information as to what relief the speedy enactment of the bill (S2812) to encourage and promote the mining of coal, phosphate, oil, gas, and sodium on the public domain will give to the threatened shortage in the supply of crude oil. 16 pages, 8vo. Washington, Government Printing Office, 1918.

U. S. Department of Agriculture: Bulletin No. 713. A Study of Farming in Southwestern Kentucky, by J. H. Arnold, Agriculturist. 19 pages, 8vo. Washington, Government Printing Office, 1918.

Concrete Shipbuilding in Spain, 4 pages, illustrations, 8vo. *Concrete Building Block and Brick,* 23 pages, illustrations, 8vo. *Facts About Concrete Roads. The Roads That Help,* 19 pages, illustrations, 8vo. *Concreting in Cold Weather,* 19 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1918.

CURRENT TOPICS.

Developing a Gauging System. E. OBERG. (*Machinery*, vol. 25, No. 2, p. 93, October, 1918.)—One of the most complete systems of gauging for the manufacture of ordnance is that developed by the Pratt & Whitney Company for the manufacture of modern rifles. A modern rifle has from 60 to 125 parts, according to its design, and requires about 700 machining operations for its completion. For that work not less than 1750 working gauges are required. An equal number of inspection gauges are used, and for every inspection gauge there is one reference gauge, so that altogether there are, in one set, 5250 gauges.

Gauging systems and interchangeable manufacturing are so closely related that it would be impossible to discuss one without dealing with the other. The main object in the introduction of interchangeable manufacturing was to reduce costs by standardizing the manufacturing operations and reducing the time required in the assembling of the mechanism. A secondary advantage is thereby gained, of interchangeability of parts. The latter advantage has become an object equally important with the reduction in the cost of assembling. As an example of the reduction of cost in assembling by the adoption of an adequate gauging system, it may be mentioned that the cost of assembling a certain rifle was $2.50. By the adoption of a new tool and gauge equipment, which resulted in the scrapping of the former tool and gauge equipment, valued at $80,000, the cost was reduced to 25 cents.

Interchangeability is sometimes carried too far, when the object sought is merely to facilitate assembling, any further refinement to insure absolute interchangeability involves useless expense. Very few mechanisms, in fact, are absolutely interchangeable. Even in rifle manufacture there are a few cases where matching of parts is permissible, this practice being known as "selective assembling." It is therefore necessary that proper judgment be used in determining upon the importance of interchangeability, and that the various factors be carefully weighed against each other.

It is generally assumed by those who have had no direct experience in devising gauging systems for interchangeable work that it is a comparatively simple matter to determine proper tolerances and limits. It has, however, been proved many times in ordnance and small arms work that without a most careful consideration of the many factors that enter into the production of a part, the cost of manufacture may be increased beyond all reasonable limits. The rule that the designer of the mechanism and the designer of tools and gauges must work constantly together cannot be too strongly emphasized. The most important subdivision of the whole subject of establishing a gauging system is the determination of suitable tolerances. It should be emphasized that the original design should require as few fits as possible, and liberal clearances should be provided in every case where there is no actual fit.

The first principle that must be considered in the establishment of tolerances—and one that is the most often ignored—is that tolerances should not be determined with reference to what would be the minimum tolerances that could be obtained by modern machining methods; but they should be established with reference to what are the maximum tolerances permissible in the mechanism without interfering with its proper purpose and action. Great difficulty is experienced with designs that do not provide for initial clearance on the original drawings. The designer, while not considering tolerances, should decide upon the kinds of fit required, which, in turn, makes it possible with the maximum metal dimensions, thus providing for the initial clearance at the time the design is made.

In general, there is a misconception as to the tolerances ordinarily permissible in the building of machines and other mechanisms. It is generally believed that the tolerances on what are considered refined mechanisms are much smaller than they really are; and unless designers thoroughly study the subject, they are inclined to require tolerances that are by no means necessary. It is possible, by the application of expensive machinery operations, to obtain an accuracy of 0.001 of an inch, or even less, but when not essential, such accuracy is highly undesirable from the point of view of economy in manufacture. The rifle is a highly accurate mechanism, and, generally speaking, the tolerances might be considered as small as the tolerances in any other mechanism, yet the average tolerances on the important dimensions of a first-class rifle are about 0.004 of an inch.

The first and most vital principle to be observed in the development of a rational gauging system is to have the locating points in the jigs and fixtures for the machining operations agree with the points used for gauging the work. Unless the gauging is done from the same points as are used for locating the work in the jigs and fixture, it will be found impossible to obtain a product that will be interchangeable.

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